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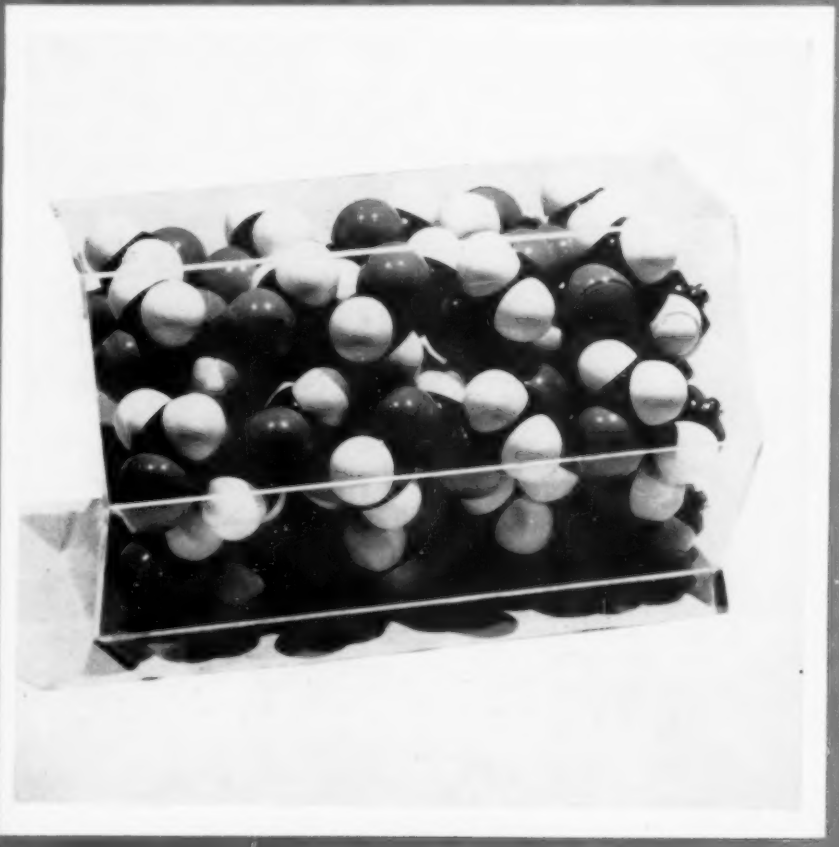
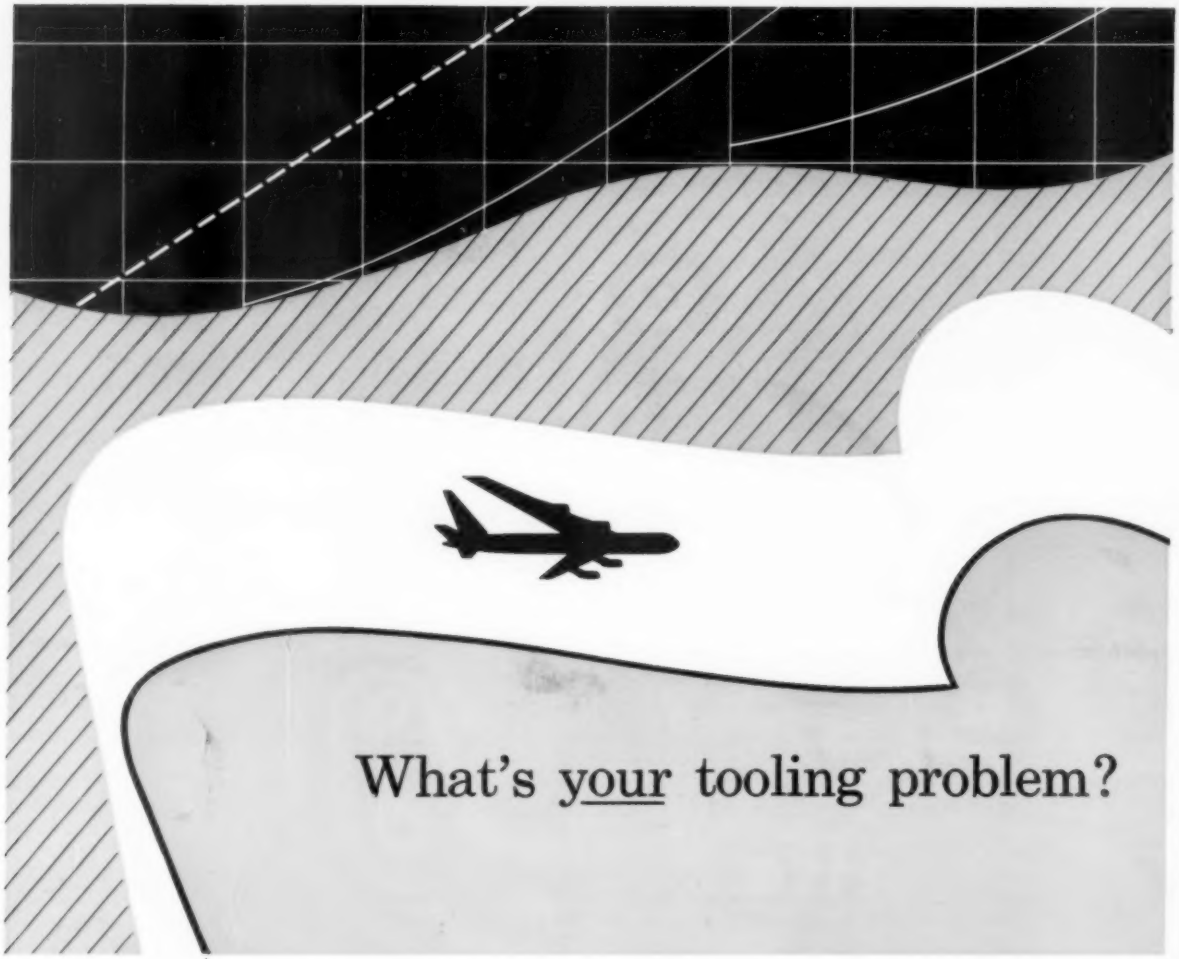


POLYOXYMETHYLENE—A NEW THERMOPLASTIC MOLDING COMPOUND

(Story on page 25)

APRIL 1958 • VOLUME 14 NUMBER 4



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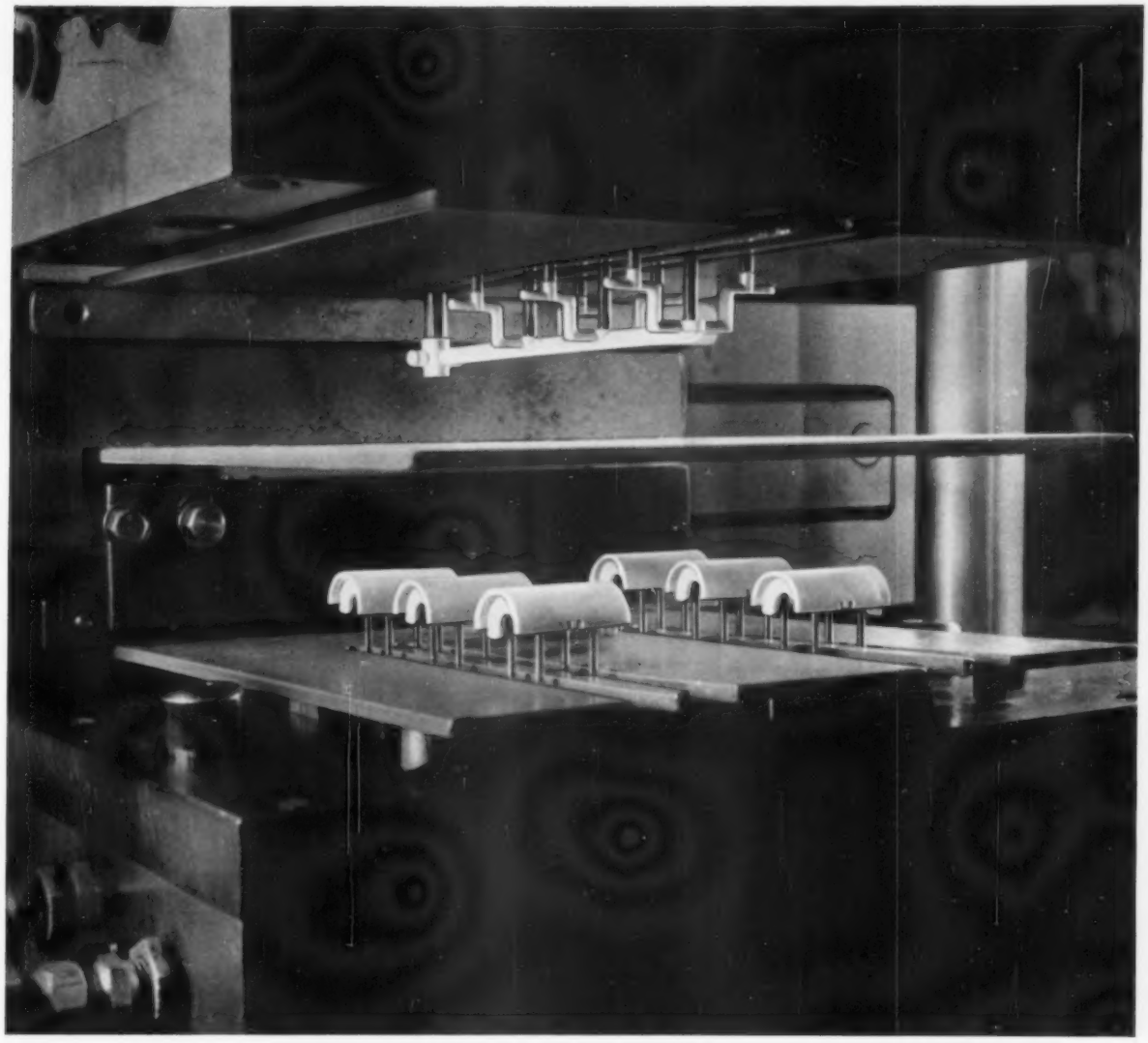

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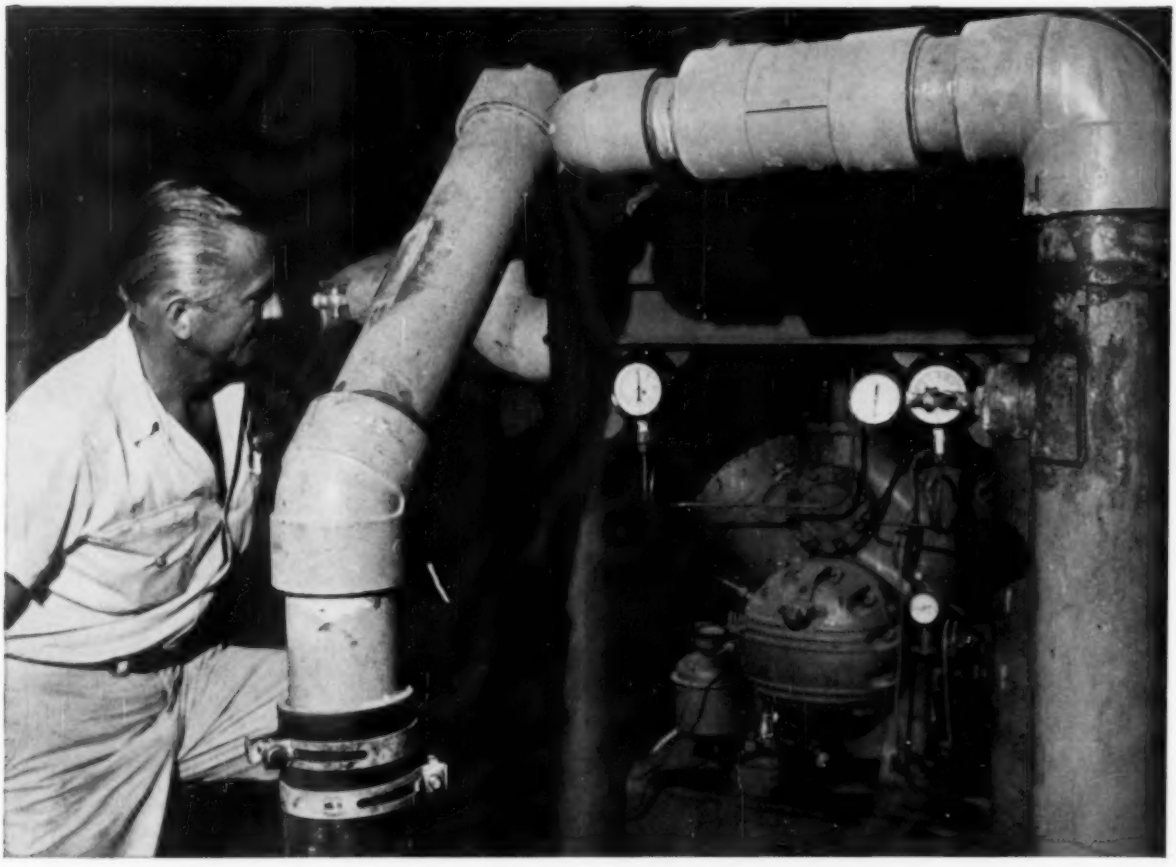

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From the Editor's Notebook

By JESSE H. DAY

● A NEW SERVICE TO OUR READERS—If you would like to have a copy of any material in this issue or any previous issue of the SPE Journal, it is now available at nominal cost. We have just completed arrangements to have all issues of the Journal stored on microfilm. You may obtain complete information on this service by writing University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

● EDITORIAL MATERIAL FOR JUNE—Commencing with the June issue, the Journal will be published from the National Office in Greenwich, Connecticut. To avoid delay and possible missing of deadlines any material planned for this issue should be mailed to the Greenwich office. The confusion of moving will be lessened if your material can be sent in well ahead of your deadline.

● PAPERS FOR 15th ANTEC—On page 57 of this issue, Program Chairman, Alex Sacher, writes an open letter to members giving "last call" for technical papers for the 15th Antec and a list of PAG Chairmen to contact should you desire to help organize a proposed session.

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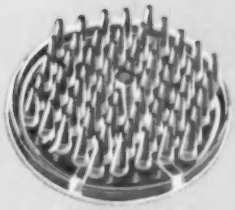

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Elongation in Tension (D638-52T), per cent	3.2
Flexural Strength (D790-49T), psi	17,300
Modulus of Elasticity in Flexure (D790-49T), psi	5.2×10^5

Values from Miscellaneous Tests

Heat Distortion Temp. (D648-45T) (¼ in. thick, 264 psi) deg. F.	200
Thermal Coefficient of Linear Expansion (D696-44 per deg. C.	7×10^{-5}
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Rockwell Hardness (D785-51)	M83

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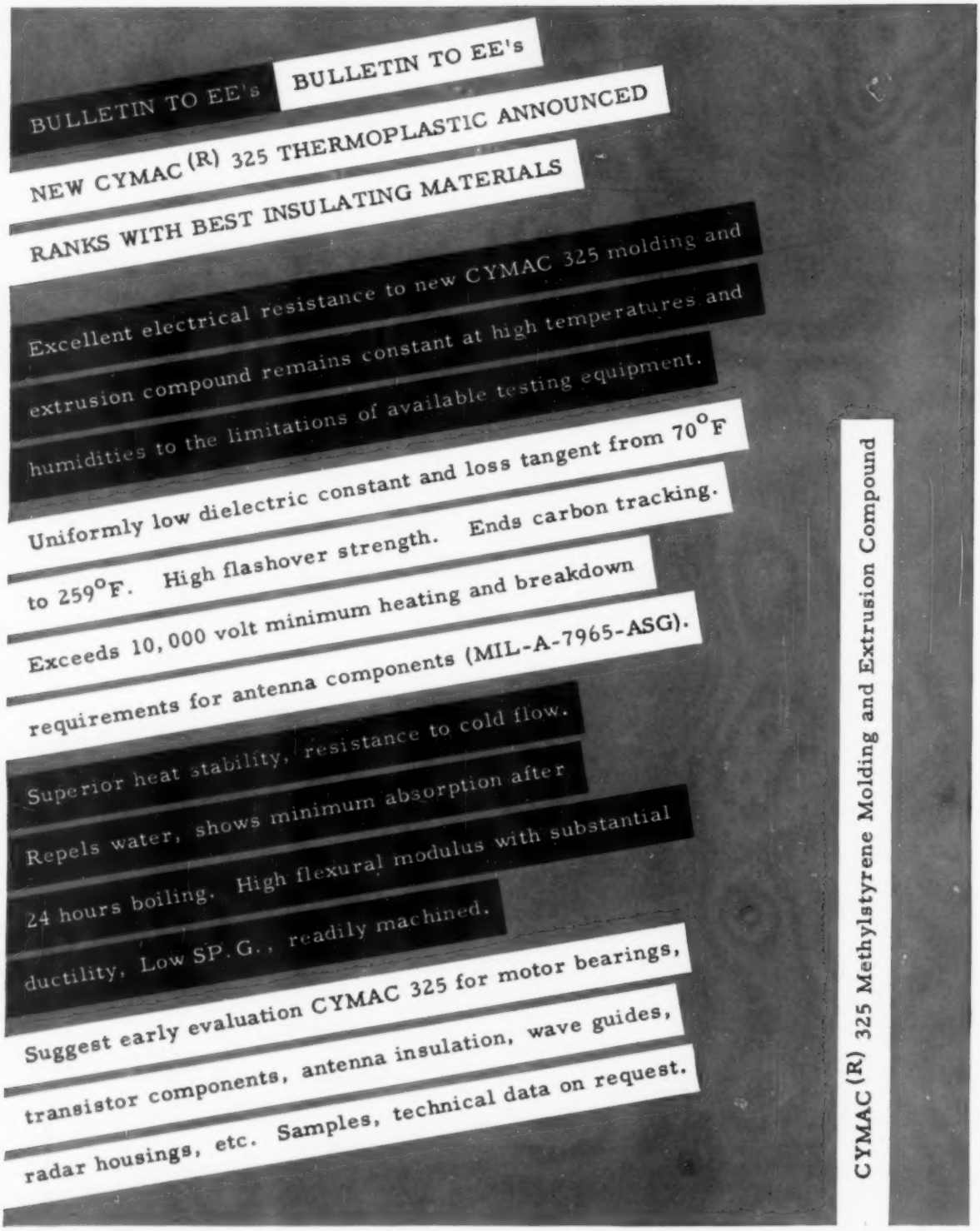
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Plastics in the Automotive Industry
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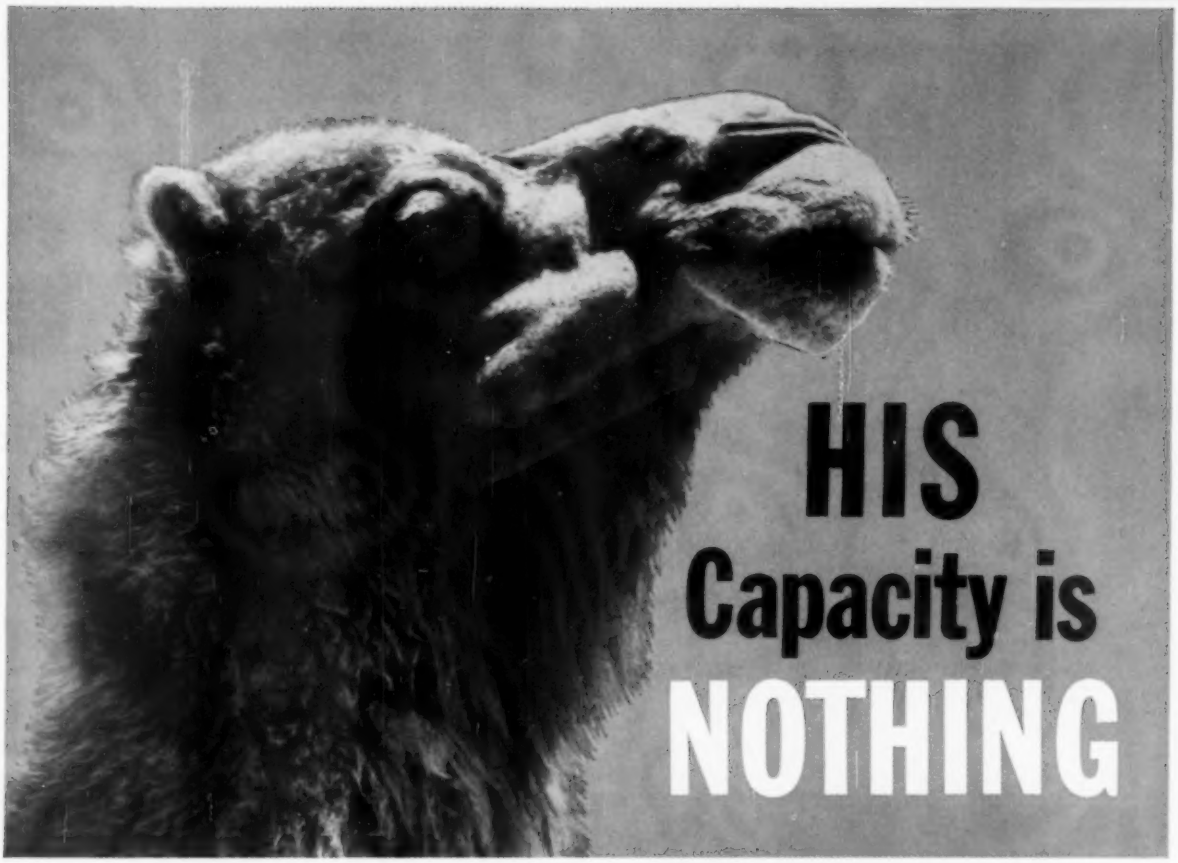

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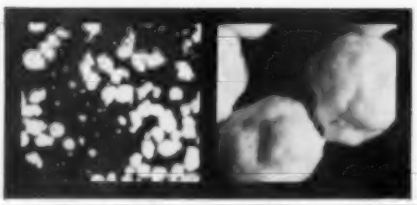

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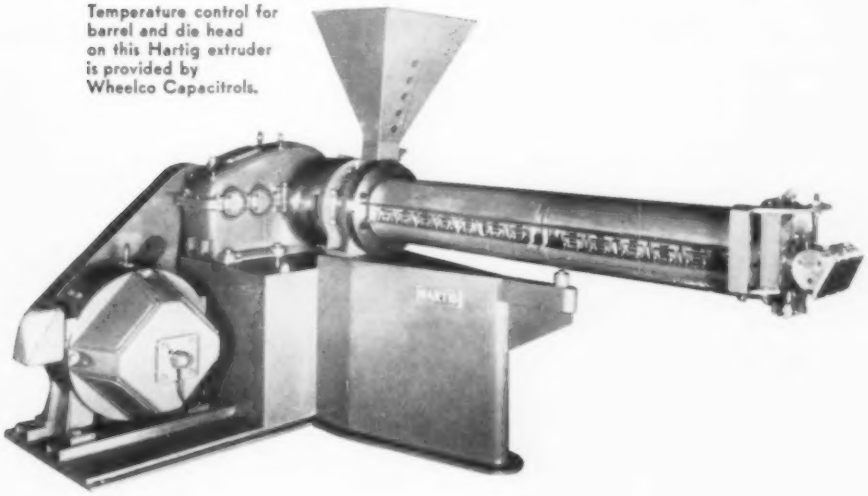

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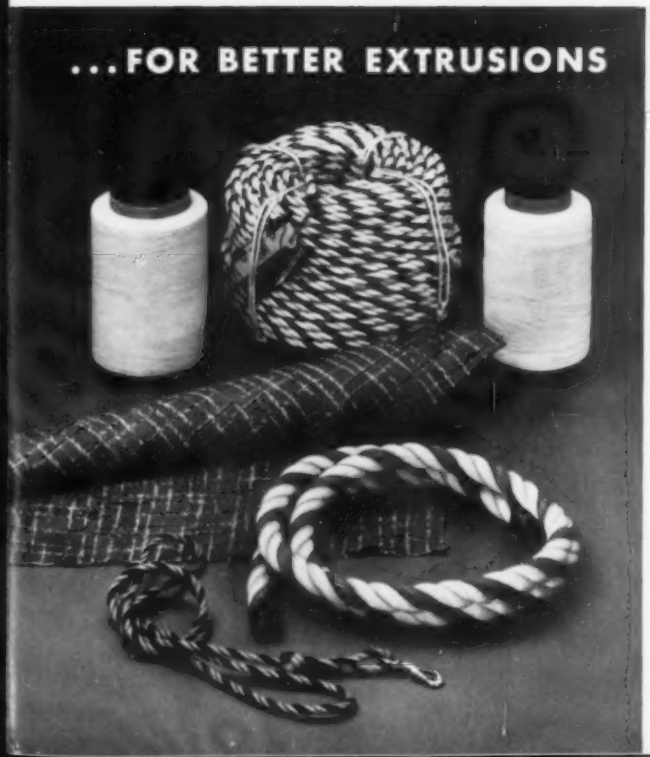

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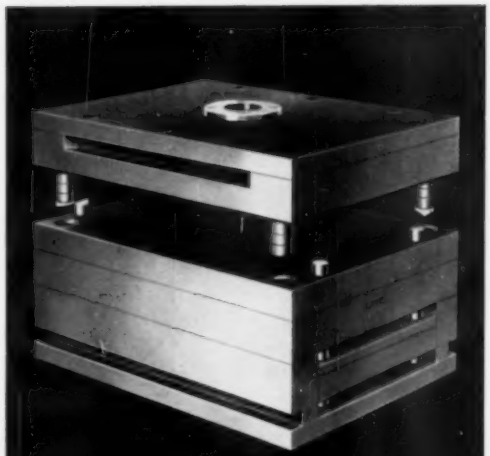

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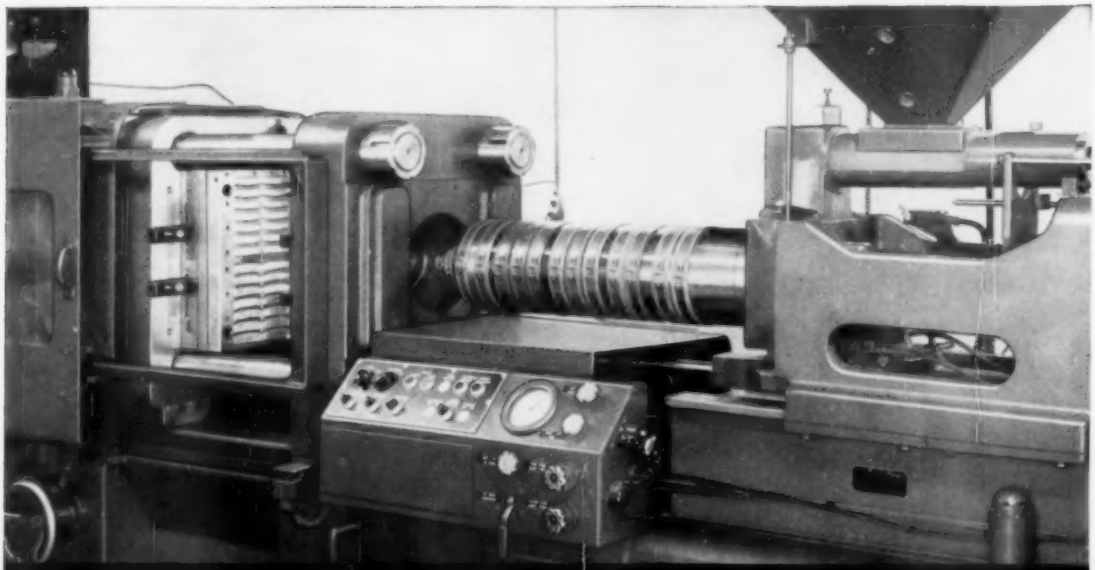
NEW REED JUMBO HEATERS...



At Superior Comb Co., Leominster, Mass., this 300TA—12/16 oz. REED, equipped with a Jumbo heater, is running a 56-cavity comb mold for National Comb Co. On a similar 24-cavity styrene comb shot weighing 8½ oz., Superior cut cycle time 25% with this machine and increased production by over 1,000 combs per hour.

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This new REED Jumbo, available as optional equipment, is the best heating cylinder you can get today. Another product of advanced Reed-Prentice engineering, the Jumbo is the only heater to give you all these advantages:

Greater capacity — The Jumbo is big, and built to handle more material per hour. You're assured of fast, thorough plasticizing with close, three-zone temperature control. Shrink-fit construction of torpedo means better heat transfer, and no drag on fins.

Faster molding — You run heavier shots, fill the mold faster, and cut cycle time. The Jumbo operates at lower temperatures, helps you reduce curing time in the mold.

Leakproof construction — REED engineers have developed a new, three-piece construction for the Jumbo. This means you have *only two seams*, and far less chance of leakage than with other heating cylinders.

Easy to clean — Special features make it easier to remove, disassemble and clean the Jumbo when necessary. With this new REED heating cylinder, you lower your heater maintenance.

Jumbo heaters are available for these REEDS: 175T (and TL) — 4/6 oz.; 275T — 8/10 oz.; 300TA (and TL) — 12/16 oz.; 400 T — 16/20 oz. For further information, call your Reed-Prentice Sales Engineer today.

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SAYS JOHN J. BACHNER,
President of Chicago Molded Products Corp.

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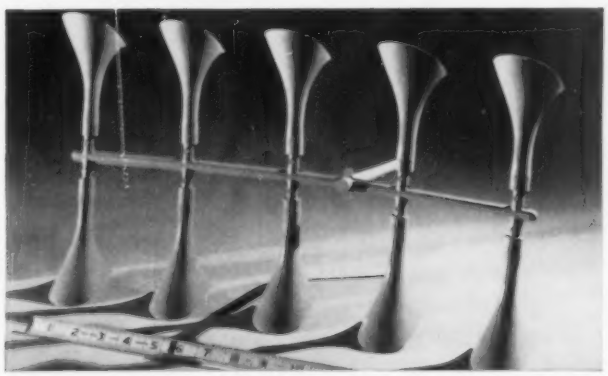
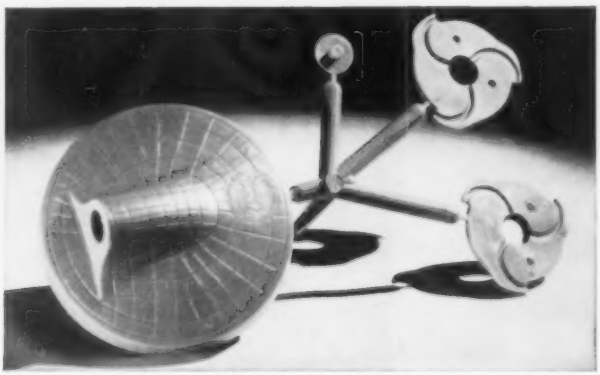


This 10-cavity shot of ladies' shoe heels weighs 24 oz. in acetate. A 300TA – 12/16 oz. REED equipped with the new Jumbo cylinder handles this job on a 65-second cycle.



Missouri Valley Plastics Co., Inc., Kansas City, Mo., uses a 175T – 4/6 oz. REED, with built-in stuffing arrangement and Jumbo cylinder, to mold these auto washing brush parts. The 6½ oz., 4-cavity shot is high-impact styrene.

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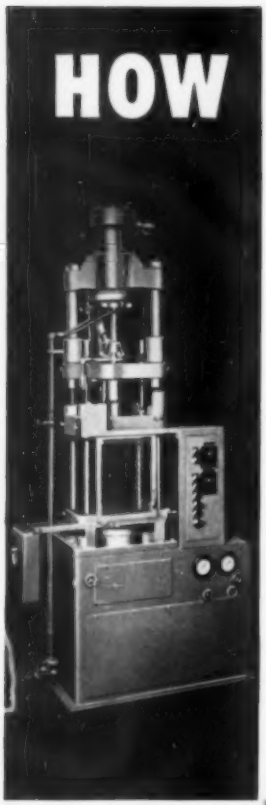

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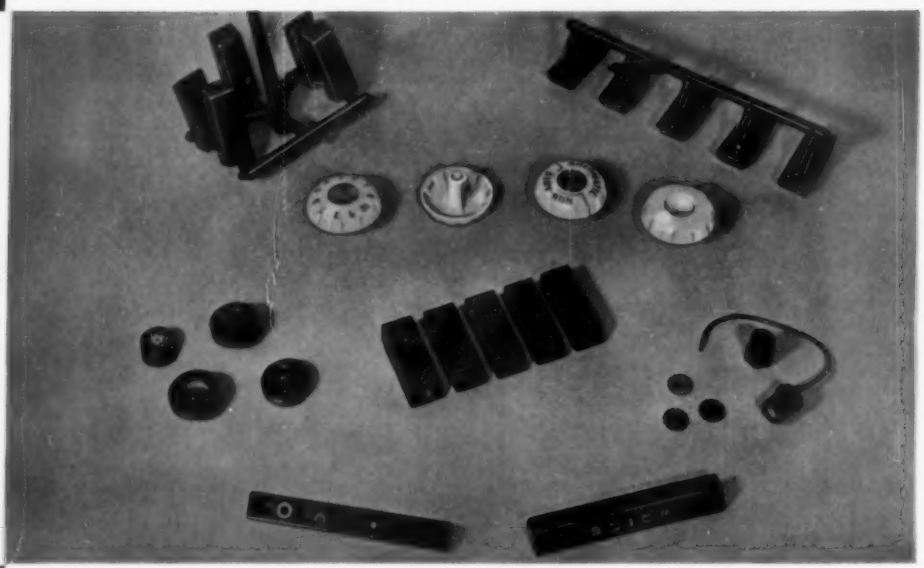

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WRITE FOR THIS GUIDE TO INCREASED PRODUCTION!

Just off the press bulletin tells what is available in the W-S line of vertical injection molding machines. Gives design features, specifications, capacities, dimensions, etc.

WS-16

A report from Du Pont on . . .

11 formulations of ZYTEL® nylon resin

The following formulations of ZYTEL offer an extensive range of variations in such properties as melt viscosity, rigidity of final product, temperature rating, solubility in chemicals. By selecting the correct formulation, you can do a better job of coordinating end-use requirements with available fabrication techniques. All formulations offer the basic advantages of ZYTEL nylon resin: its high strength-to-weight ratio; its toughness, impact strength, abrasion resistance; its versatility with regard to production processes. Du Pont engineers will be glad to work with designers, processors and fabricators in selecting optimum compositions for specific uses.

101 Highest-melting resin with high fluidity at molding temperatures; has good machineability, high impact strength with maximum stiffness. Molded or extruded. For general-purpose moldings such as mechanical parts, consumer items.

103 Comparable to ZYTEL 101, but stabilized for extended operation at elevated temperatures. Molded or extruded. For electrical parts, coil forms, fastening devices.

105 Black composition with excellent weathering characteristics, comparable to ZYTEL 101 in general properties. Molded or extruded. For automotive parts, electrical parts, weather-resistant moldings.

42 A high-viscosity extrusion grade generally comparable to ZYTEL 101. Extruded. For tubing, film, bottles, extruded shapes.

31 Offers lower moisture absorption and greater flexibility than ZYTEL 101. Molded or extruded. For wire jacketing, special mechanical moldings.

33 Thermally stabilized extrusion grade comparable to ZYTEL 31. Molded or extruded. For wire jacketing, electrical parts.

37X Black nylon stabilized against weathering and thermal degradation offers low moisture absorption and excellent toughness. Molded or extruded. For wire jacketing, weather-resistant moldings.

211 Semi-rigid composition offering a combination of high impact strength and resilience. Molded or extruded. For impact devices and parts requiring exceptional toughness.

3606 A heat and light-stabilized flexible composition. Extruded. For wire jacketing, particularly field wire.

63 A flexible composition which is soluble in alcohol, but has good resistance to gasoline and oil. Flow characteristics are comparable to conventional thermoplastics. Molded, extruded or used in solution. For wire jacketing, sheeting, packings, seals, textile coatings.

69 A more flexible composition than ZYTEL 63, with superior resistance to impact and flexural fatigue. Molded, extruded or used in solution. For jacketing mechanical cables and ropes, and for impact devices.

• • •

All compositions are packaged as solid granular materials. Some of the types are available in colors. For details on the physical properties of these formulations and a description of many of their end uses—

WRITE TO: E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room 404, Du Pont Building, Wilmington 98, Delaware. In Canada: Du Pont Company of Canada (1956) Limited, P.O. Box 660, Montreal, Quebec.

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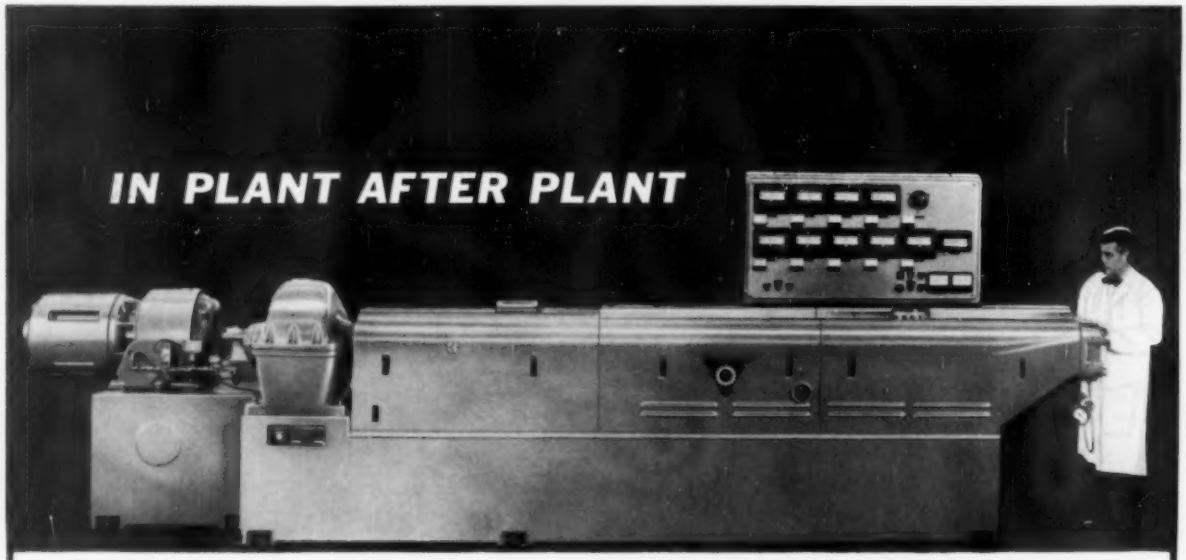

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THE SOCIETY OF PLASTICS ENGINEERS JOURNAL

Volume 14, Number 4 • April, 1958

Creep in Polyethylene at Elevated Temperatures

R. R. Dixon

Westinghouse Electric Corporation
Electric Appliance Division
Columbus, Ohio

With the announcement of low pressure, high density polyethylenes in production quantities, there was an inevitable rush to try to use this material in difficult applications. The well-known toughness of conventional polyethylenes, combined with the increased stiffness and high practical heat distortion, made the material ideal in the eyes of design engineers and injection molders for replacement of other materials. Where conventional polyethylenes were obviously too flexible for structural purposes, the higher flexural modulus of these new materials made them available for increased design possibilities. Also, the freely quoted sterilizing tests indicated to far too many people that here was a plastic that could be used structurally in warm atmospheres.

Design Limitations

Because of these improved properties, many engineers were swamped with requests to change this or that part or design some other part in order to take advantage of them. In most of these cases the part being considered was something structural—supporting either a continuous load or an intermittent load—and in many cases this loading occurred at temperatures up to 200°F.

An example of such a request involved an insulating support in a refrigerator. There was urging from sales and design people to use high density polyethylene as evaporator supports, because of its rigidity and toughness. The fact that there was a subsequent operation which involved considerable stress and temperatures around 250°F was not considered to be a problem for such a high temperature material. Published data on A.S.T.M. heat distortion were sufficient to discourage this application.

Although it is obvious to most that high density polyethylene will not hold even a moderate load at 200°F, it is not so obvious how much load can be supported at any particular temperature. A.S.T.M. heat distortion values give an indication of load carrying ability, but are nothing that can be used as design information. Furthermore, such information is not yet readily available from all the materials suppliers.

Investigating sustained loads at various temperatures means measuring creep or flow over extended periods of time, thus tying up equipment for a long time for a relatively few bits of data. It is quite understandable that there is reluctance to determine creep curves when there are so many other important properties to be investigated.

However, since creep and stress rupture are definite limitations in some applications, the work described here was started in order that a guide might be available for design limitations. Creep values were measured in tension at several temperatures and several loadings. Tests were terminated at four hours.

It should be pointed out that the procedures and the data were by no means precise. Results can be used only as a guide, but they should be satisfactory for design purposes for short time loading. It is expected that more precise information will be made available by the industry when the need becomes more widely felt.

Test Method

Tensile creep was determined in a Tinius-Olsen Plastiversal, using an R2S strain gage on a two inch gage length. The strain signal was recorded at a forty magnification. A static load was applied at time zero to give the initial strain deflection. At intervals after that, small loads were applied above the specimen (without affecting the loaded specimen) to give indexing marks on the

strain plot. The strain values were read using a magnifying glass.

For determining values at elevated temperatures, a box around the tensile clamping jaws was heated by blowing hot air through a coiled perforated aluminum tubing inside the box. The temperature could be controlled to ±1°F. The system was brought up to temperature before the load was applied. In order to load the sample, the box had to be opened, and the early part of the strain-time curve showed thermal contraction effects until the temperature had recovered.

Samples were injection grade standard materials supplied by several companies as injection molded A.S.T.M. tensile specimens. Melt index was in the range of 1.0 for the high density materials. These were tested in the "As Received" condition. Samples included a low density polyethylene and two high density polyethylenes.

Test Results

Results of the low density polyethylene creep tests are shown in Figure 1. Several factors mentioned earlier may be observed on this plot. First, the thermal recovery shows its effect in the early part of the test, about the first ten minutes. Secondly, the points appear to give a very good straight line on a log-log plot; those varying from the straight line can be accounted for by thermal expansion. These points were better than were expected in the planning stages of this work. Relative slopes of these curves are, from top to bottom, .099, .072, and .078.

In Figure 2 are values for a Ziegler type polymer, with the first ten minutes omitted from the graph. The

Figure 1.

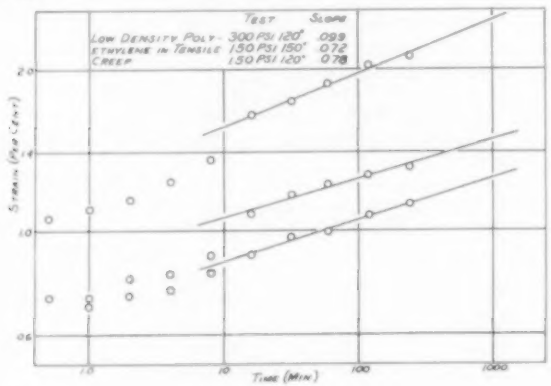

Test Slope
Low Density Poly- 300 PSI 120° .099
ethylene in Tensile 150 PSI 150° .072
Creep 150 PSI 120° .078
Strain (Per Cent)
Time (Min)

Figure 2.

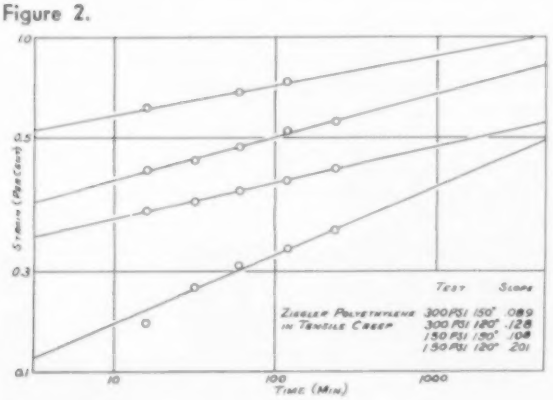

Test Slope
Ziegler Polyethylene 300 PSI 150° .089
in Tensile Creep 300 PSI 180° .128
150 PSI 150° .108
150 PSI 120° .201
Strain (Per Cent)
Time (Min)

Figure 3.

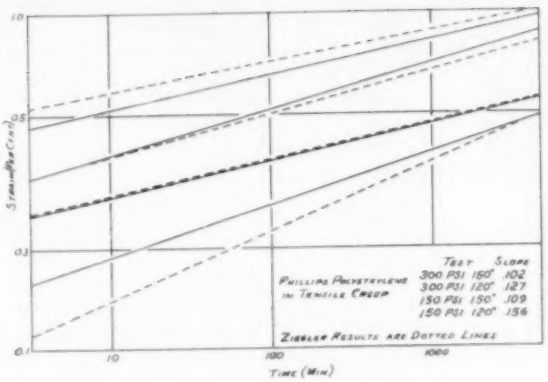
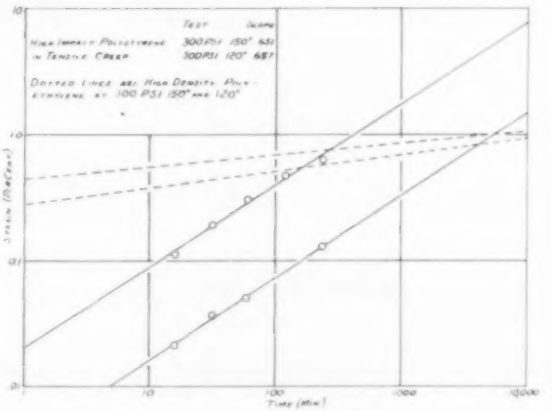

Test Slope
Phillips Polyethylene 300 PSI 150° .102
in Tensile Creep 300 PSI 120° .127
150 PSI 150° .109
150 PSI 120° .156
Ziegler Results are Dotted Lines
Time (Min)

Figure 4.


Test Slope
High Impact Polystyrene 300 PSI 150° .651
in Tensile Creep 300 PSI 120° .687
Dotted Lines are High Density Poly-
ethylene at 100 PSI 150° and 120°
Time (Min)

slopes are, from top to bottom, .089, .128, .108, and .201. Figure 3 shows a Phillips type polymer superimposed on Figure 2. There slopes are .102, .127, .109, and .156. It is obvious that there was very little difference, if any, in creep properties of these materials, at least on this brief test.

It has already been pointed out that the data are not precise because of equipment limitations (e.g. presence of vibration, absence of a standard for temperature correction, use of uncontrolled specimens, and difficulties in reading small strain values; also, shrinkage of the polyethylene at elevated temperatures may mask the true creep. Thus the greatest value of the test results is in the general picture which is presented. It could indicate to those sales engineers and design engineers who do not recognize the problems of creep in high density polyethylene that in a constant load application at a particular temperature, a definite amount of creep must be taken into account.

The second point of note is that under the test conditions the creep rate was slightly greater in high density polyethylene than it was in low density polyethlene. However, because of the higher initial deflection in the low density material, total deflection remained higher for this material when extrapolated by a straight line to many years. Since it has been shown in the literature (1) that correction factors must be added to get a straight line function, longer time creep tests must be conducted to get

(Please turn to Page 70)

"Delrin" – A New Thermoplastic

J. F. Cogdell and R. H. Hardesty

E. I. du Pont de Nemours & Co., Inc.
Wilmington 98, Delaware

A new thermoplastic has been created, different from any other thermoplastic in chemical structure and physical properties. It is a high-melting, highly crystalline, polymer of repeating—CH_2O—groups. "Delrin"* acetal resin is its trade name. This paper discusses the physical properties of this new thermoplastic, its processing characteristics and something of the program of end-use tests to establish its general utility.

When a new material is discovered, its value as a commercial product must be determined. The study presented in this paper used a combination of investigating techniques in reaching the conclusion that this new thermoplastic represents a significant advancement in the field of engineering plastics.

Early tests showed the new polymer to have an excellent combination of properties: high strength, excellent flexural modulus and fatigue life, outstanding resilience and toughness. However, since a material is subjected to many different environmental conditions in various end uses the effects of environments on the properties of the polymer were studied. These showed the new polymer to have the unusual feature of retaining a significant degree of its desirable end-use properties, including dimensional stability, under conditions of high temperature and humidity during an extended period of stress or during exposure to most solvents.

Knowledge of the properties of a new material provides a foundation for prediction of possible end-uses. Simple qualitative prediction is not enough.

An extensive end-use test program carried out within the company has now been expanded to a test program with end users and processors. Tests on selected applications in actual or simulated service confirm the suitability of "Delrin" for most of the applications studied in such areas as packaging, pipe, automotive, appliances, machinery, plumbing, hardware and consumer items.

Testing facilities and polymer availability were not sufficient to allow testing of all the end-uses that needed to be studied so a technique of projected applications was used. Here, knowledge of the end-use property requirements and economics of specific uses was used to make actual design and cost calculations.

Processability, which is just as important in a material as good physical properties, had to be determined. Fabrication studies, property determinations and fabrication of end-use test items show that this new resin can be processed without difficulty in standard thermoplastic equipment. In order to develop a feel for this material in relationship to the processability of existing thermoplastic materials, a study was made of the basic melt viscosity of the new polymer. Equipment and operating conditions recommended for injection molding and extrusion have been determined, and recommended procedures for the design of molds for close tolerance injection molding have been established. Suggested extruder screw designs for the polymer have also been developed. Some important characteristics related to the fabrication of this thermoplastic are ability to fill a multi-cavity mold, ease of ejectability, ability to hold necessary molding tolerances for mechanical parts, and good retention of inserts.

The new polymer is a development material which is not yet available commercially. The material produced now in a small semi-works is being used exclusively in a highly selective program designed to obtain even more data on product properties, processability and suitable end-use areas. Work has been done with two types of resin: "Delrin" 500X for general purpose molding and "Delrin" 150X for general purpose extrusion. It is expected that the polymer will be available commercially in mid 1959.

**Du Pont registered trademark*

Figure 1. The Chemistry of Polymer Formation.

$$(n+2)\ CH_2O + H_2O \xrightarrow[\text{CATALYST}]{\text{IONIC}} HOCH_2O(CH_2O)_nCH_2OH$$

$$n = 100\text{-}200$$

Figure 2. Molecular Model of Acetal Polymer.

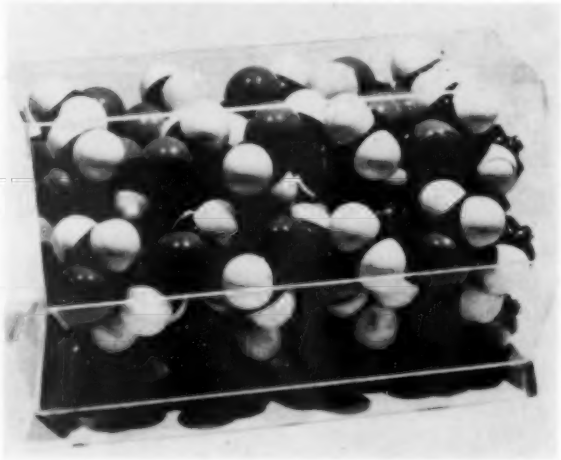


Figure 3. The Polymer has both Crystalline and Disordered Regions.

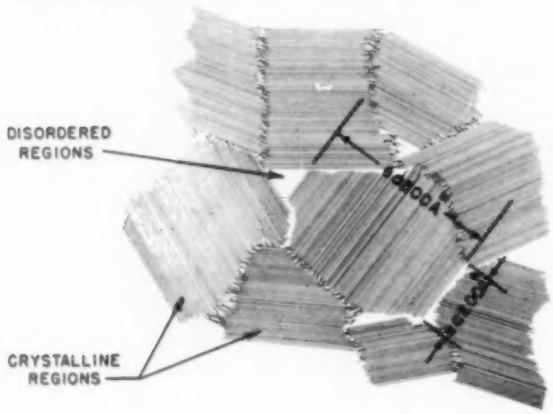
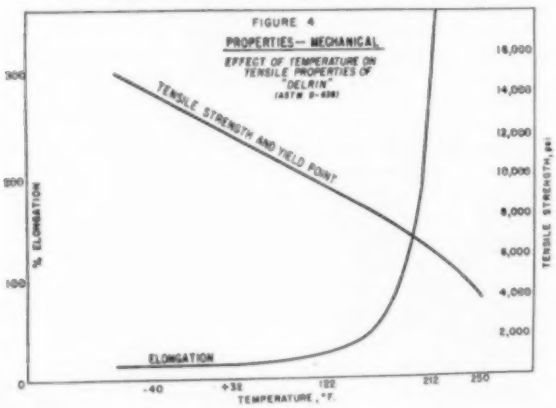


Figure 4. The Mechanical Properties of Acetal Resin.



The building unit for acetal resin is formaldehyde, a simple molecule with exceptional reactivity. The historical polymerization of formaldehyde is typified by formaldehyde in water with an ionic catalyst to produce a low molecular weight solid (Figure 1), having poor mechanical properties and low thermal stability. An altogether novel, stable superpolyoxymethylene resulted from the discovery of a new polymerization system and a unique method of stabilization. The molecular structure involves unbranched polyoxymethylene chains (—OCH_2 OCH_2—) of great length, normally averaging more than 1,000—CH_2O-units. Thus the polymer is a linear acetal resin.

The solid structure of this polyoxymethylene is the basis for its exceptional mechanical properties. On solidification, polyoxymethylene chains develop supramolecular structure involving partial crystallization. Each molecular chain is dense and of high lattice energy (Figure 2). Crystalline and disordered regions combine to form hyperstructures which impart rigidity, strength and resilience to the polymer (Figure 3). The length of molecular chains results in interconnection of the chain crystals which comprise about 75% of the polymer. From this, it is easy to see that this polyoxymethylene is an extremely dense, highly crystalline polymer.

Physical

The properties of this acetal resin are listed in Table I. Information of this type is not, in itself, enough to permit a real insight into the design capabilities of a polymer. Therefore, a detailed study was made of all properties of the polymer necessary for a thorough understanding of its design possibilities.

In making these data more meaningful, it was necessary in some instances to make comparisons with other materials. The comparisons were not made to disparage other materials but are a serious attempt to define something new by comparison with something that is familiar.

Strength and Stiffness

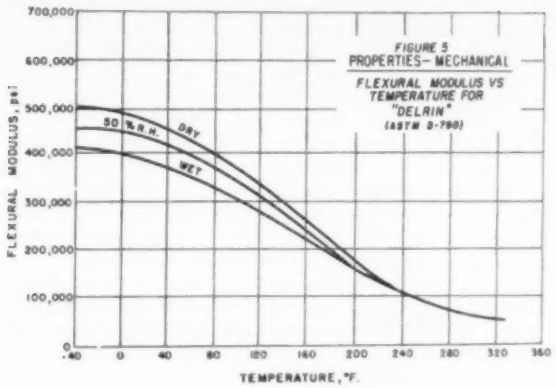
This acetal resin at room temperature has an elongation of 16% and a tensile strength of 10,000 psi with no true yield point. At higher temperatures, particularly around 212°F., there is a well defined yield point and considerable elongation, 350 to 500%. Like all thermoplastics, superpolyoxymethylene decreases in tensile strength and increases in elongation with increasing temperature (Figure 4); however, it does retain much of its tensile strength at 250°F. Moisture has almost no effect on tensile properties (less than 10%).

The flexural modulus or stiffness of the dry polymer at room temperature (Figure 5) shows it to be one of the stiffest thermoplastics. This is a significant design property, but more important is the excellent retention of high flexural modulus under conditions of high temperature and humidity. At room temperature, the modulus decreases by about 5% as the relative humidity increases from 0 to 50%. An increase from 0 to 100% relative humidity decreases the modulus only 20%. After twelve months exposure at 122°F. to solvents like carbon tetrachloride, ethanol, acetone, ethyl acetate and toluene there is a 30 to 40% drop in flexural modulus, but this is accompanied by less than a 7% decrease in tensile yield strength.

Creep and Cold Flow

All plastics exhibit a gradual deformation called creep or cold flow when they are subjected to a continuously applied load. At room temperatures and under moderate loads, this polyoxymethylene will creep more than amorphous polymers such as polystyrene or polymethylme-

Figure 5. Flexural Modulus of Acetal Resin.



thacrylate but less than crystalline polymers such as polyethylenes and polyamides. When it is subjected to prolonged high loading at high humidities and temperatures, this polyoxymethylene shows much less creep than other typical thermoplastics (Figure 6).

When the stress level and the total deformation of a part are known, a value for the modulus of elasticity can be calculated at a given time. Due to creep, the flexural modulus appears to decrease from the instantaneous value of the modulus as determined in standard high speed tests. This reduced value of the modulus, which allows for both initial strain and cold flow, is called the "apparent modulus". The apparent modulus at four temperatures is plotted in Figure 7.

Most of the changes in mechanical properties which occur under conditions of stress are temporary, elastic-type changes, and the original values will return when the stress is relieved, assuming that the stress is not so high as to cause permanent deformation. Although the polymer resists bending, it recovers very well once it has been deformed (Figure 8). In this respect it is somewhat like steel. To deform it at all requires a lot of force, and if it is not bent too far, it recovers almost perfectly. This excellent recovery from loading makes it an ideal material for a snap-fit assembly.

Tensile creep behavior under continuous stress at 77°F. (Figure 9) shows the ultimate tensile strength to be leveling off at about 5000 psi.

Figure 6. Creep of Acetal Resin Compared With Other Plastics.

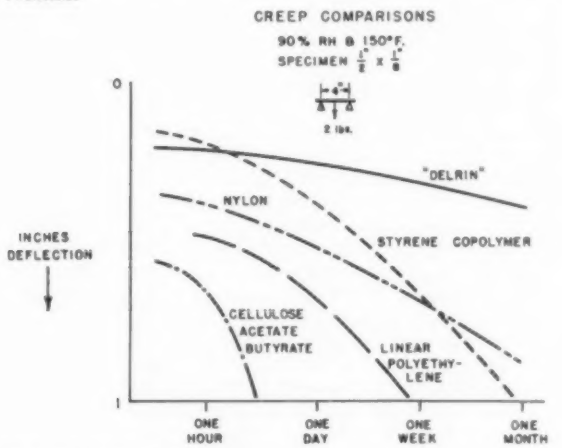


Figure 7. Flexural Modulus as a Function of Temperature and Time. Stress Level 1,500 psi.

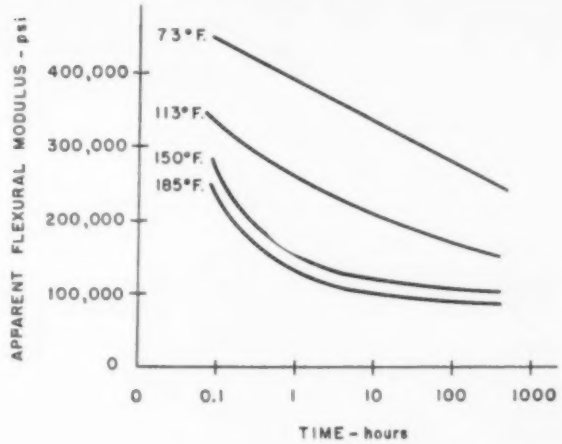


Figure 8. Recovery from Loading.

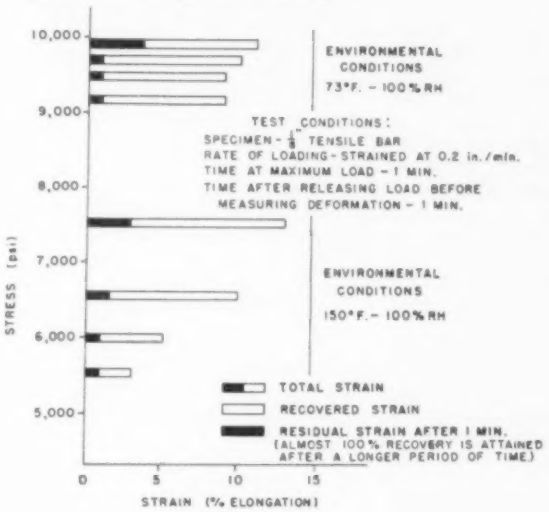


Figure 9. Tensile Creep Behavior of Acetal Resin.

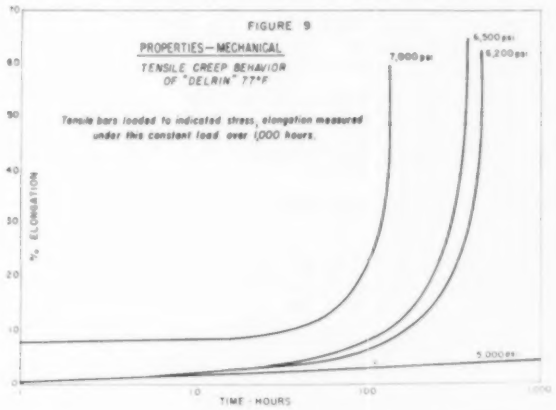
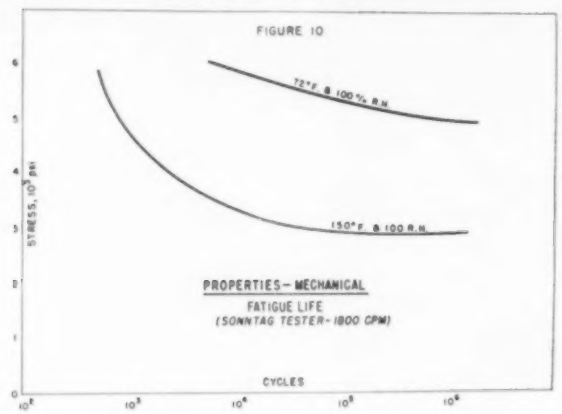


Figure 10. Fatigue Properties of Acetal Resin.



Fatigue

All materials, when subjected to a repeated cyclic stress, will ultimately fail at a stress lower than the static strength. This phenomenon is known as a fatigue failure.

Our experiments suggest that like the ferrous alloys, there is a stress value below which this new resin will not fail no matter how many times the load is applied. This stress is called the "fatigue endurance limit".

Figure 10 shows the fatigue life under different environmental conditions. At 72°F. and 100% relative humidity, it has a fatigue endurance limit of 5000 psi. This is a higher fatigue endurance limit than that obtained with any other typical thermoplastic under similar conditions. As the temperature increases, the strength of superpolyoxymethylene becomes even more apparent. The presence of lubricants or water does not decrease the fatigue life.

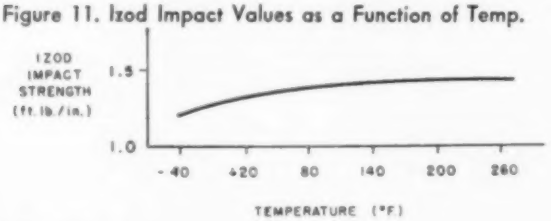
Toughness

Toughness has so far resisted all efforts of definition by any one test primarily because toughness is the result of a combination of properties, piece geometry, and environment. Ratings under one test set of conditions may vary considerably from ratings under a different set of conditions. The only reliable measure of toughness is a given application is an end-use test of that application.

For its stiffness, superpolyoxymethylene is one of the toughest, most resilient plastics known. However, there is an important difference between the toughness of this material and the more flexible materials like nylon. When thinking about the toughness or resilience of this material, it should be considered like the resilience of a steel spring rather than the elasticity of a rubber ball.

The wide variation in Izod impact strength obtained between the unnotched specimens (20.5 ft. lbs/in.) and those specimens which have either a machined or molded-in notch (1.4 ft. lbs/in. and 1.7 ft. lbs/in. respectively) emphasizes the importance of eliminating all sharp corners and other stress raisers on parts that are subjected to impact loading. When comparing Izod impact values of different materials, it is necessary to consider the fact that the more flexible a material is the better its Izod impact strength since the sample deforms more on impact and dissipates part of the impact energy. In the Izod test the sample must be broken, so the greater the deformation of the sample the greater the amount of energy which must be applied to deform and break the sample. In actual use, many of the high impact polymers deform permanently under impact loads and fail from deformation even though the part has not broken.

Figure 11. Izod Impact Values as a Function of Temp.



The effect of temperature on the Izod impact strength of the polymer is shown in Figure 11. The most important thing to note here is that even at temperatures down to -40°F., there is little loss of impact strength. This is totally unlike polymers which depend upon the presence of plasticizers for toughness and become brittle as the temperature decreases. Moisture has little effect on the Izod impact strength. As relative humidity increases from 0 to 100%, there is only a slight increase in the impact strength.

The mandrel bend test is another toughness measurement which can be used on polymers with a high degree of elongation, but it measures a different kind of toughness than the Izod impact test. In this test, a 1/8 inch thick stiffness bar is bent around a 1/8 inch diameter mandrel. A 6,6– nylon can be bent 180° around this mandrel, but a similar bar of acetal resin can be bent only 90° around this same mandrel without breaking, though it can be bent 180° around a 1/4 inch mandrel.

These data lead to the conclusion that this polyoxymethylene is tough in the sense of "strong and rigid", and should be used where high strength and resistance to bending are required.

Dimensional Stability

Dimensional changes in a plastic material are caused by three major factors: expansions or contractions resulting from temperature changes; volumetric changes resulting from water or chemical absorption or loss; and changes in shape resulting from the release of stresses frozen in the part during fabrication. Examination of data on these three dimensional stability factors indicates that this acetal resin has excellent dimensional stability. Factors contributing to this characteristic are its hardness, high crystallinity and high melting point (360°F.).

The effect of temperature on this acetal resin is defined by the coefficient of linear thermal expansion which is about 5 x 10^{-5} in/in/°F., a value approximately that for most other plastics. Water absorption is governed by both the temperature and the moisture environment (relative humidity or immersion). The equilibrium water content under normal atmospheric conditions (77°F., 50% RH) is about 0.2%. Upon total immersion in water at room temperature absorption is about 0.9%. The rate of water absorption is governed not only by the temperature and moisture environment, but by the thickness of the part. Thicker pieces require longer to reach equilibrium.

Data on the relationship between moisture absorption and dimensional changes at various temperatures are shown in Figure 12. On going from the dry or "as molded" state to equilibrium (that is, 0.2% absorption at 77°F. and 50%RH), the polymer increases in dimension by 0.1% (1 mil per inch of length). When completely immersed or saturated with water at 77°F. it will increase 0.4% (4 mils per inch). The dimensional changes which will occur in a stress-free part when transferred from one

temperature-moisture environment to another may be estimated from the same plot, Figure 12. Practical use of this chart has shown it to be accurate within ± 5%.

Experience with this resin has shown that no allowance need be made for dimensional changes caused by release of stresses as long as the parts are to be used at temperatures below 120°F. If service temperatures are to be higher, it may be necessary to anneal the parts after fabrication. The factors that determine the need for annealing are: the amount of frozen-in stress, the conditions of use and the tolerances required. The frozen-in stresses will vary both with fabrication conditions and with the geometry of the part. With most parts, it can be kept to a minimum by the use of a hot mold (250°F.). Where close tolerances (of 1 to 3 mils per inch) must be maintained at elevated service temperatures and annealing is deemed necessary, the parts should be treated by complete immersion in an organic medium such as 'Primol' D* or 'Uniflo'+ oil for twenty minutes at 300°F. As an additional benefit, this treatment will improve the wear resistance of parts such as gears and bearings.

Abrasion Resistance

The polymer has very good abrasion resistance and, in general, is superior to other commercially available thermoplastics with the exception of 6,6– nylon. This same experience has also shown that abrasion resistance depends upon so many variables that there may never be a universal test for it. For this reason, a number of different laboratory and practical tests have been run on "Delrin" and other polymers to characterize it in this respect (Table II).

Frictional Properties

The smooth, hard surface of this polymer makes it feel slippery to most people. This slipperiness is confirmed by frictional measurements on an inclined plane which shows its coefficient of friction against steel to be very low (Table III). Of particular importance is the fact that there is little, if any, difference between the static and dynamic coefficients of friction. Therefore, the phenomenon of slip-stick has not been observed with this polyoxymethylene. Also, there is no variation in the coefficient of friction over a temperature range of 73° to 250°F., and under loads of up to 2,500 psi. In addition, there is no tendency to coat the surface against which it is riding which would produce mating surfaces of the polymer.

**'Primol' is a reg. trademark of Standard Oil Co. of N.J.*
+'Uniflo' is a reg. trademark of Standard Oil Co. of N.J.

Figure 12. Dimensional Changes Due to Temperature and Moisture (at equilibrium).

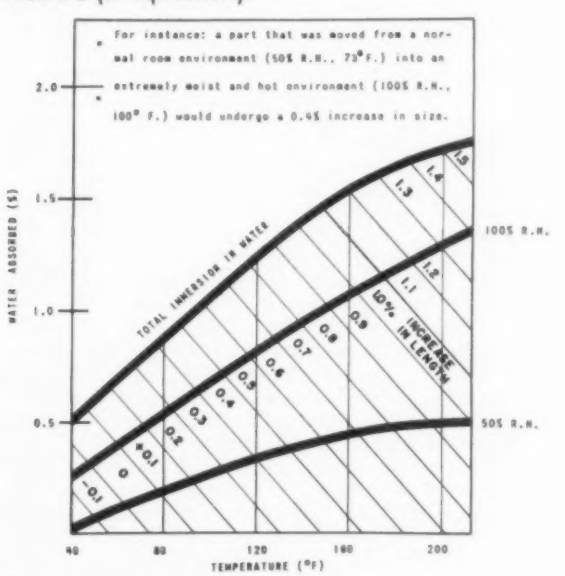


TABLE I
Typical Properties

Property	Units	ASTM NO.	Average Values* For "Delrin" 500X	150X
Elongation, 73°F.	%	D638	16	75
158°F.	%	D638	330	460
Impact strength, Izod, - 40°F.	ft.lb/in.	D256	1.2	1.8
73°F.	ft.lb/in.	D256	1.4	2.3
Tensile strength and yield point 73°F.	psi	D638	10,000	
158°F.	psi	D638	7,500	
Flexural modulus, 73°F.	psi	D790	410,000	
Flexural strength	psi	D790	14,100	
Fatigue endurance limit, 73°F., 100% RH	psi		5,000	
Shear strength	psi	D732	9,510	
Heat distortion temperature, 264 psi.	°F.	D648	212	
66 psi	°F.	D648	338	
Deformation underload (2000 psi at 122°F.)	%	D621	0.5	
Compressive stress at 1% deformation	psi	D695	5,200	
Water absorption, 24 hours immersion	%	D570	0.4	
50% RH (Equilibrium)	%	D570	0.2	
Specific gravity		D792	1.425	
Rockwell hardness		D785	M94,R120	
Flammability	in./min.	D635	1.1	
Melting point (crystalline)	°F.		347	
Flow temperature	°F.	D569	363	
Coefficient of linear thermal expansion per	°F.	D696	0.000045	
Thermal conductivity	BTU/hr/sq.ft/°F/in.		1.6	
Specific heat	cal/gm.		0.35	

*These values are representative of those obtained under standard ASTM conditions and should not be used to design parts which function under different conditions.

TABLE II
Comparative Weight Loss of "Delrin" and Other Materials in Different Abrasion Tests

Polymer	Taber	Ball Mill	Wire Drag	Sander
"Zytel" 101	1	1	1	1
"Delrin"	2-5	4-6	5-6	3-4
Polystyrene	9-26	15-20	35	—
Styrene Copolymer	9	10-20	—	—
Cellulose Ester	9-15	10-20	15	—
Hard Rubber	—	10	—	4
Die Cast Aluminum	—	—	—	4-5
Mild Steel	—	15-20	—	—

Test Descriptions:

A. Taber-CS-17 wheel and a 1000 gram load; 77°F. and 50% R.H.

B. Ball Mill-2" x $\frac{1}{2}$" x $\frac{1}{8}$" bars rolled in 5" Abbe ball mill with 25 Borundum balls and 500 ml. of water.

C. Wire Drag-Continuous loop of fine resistance wire (spirally wrapped on a cord) was pulled continuously over a cylindrical test piece. Tension held constant and cord pulled at 70 ft/min. for 30 minutes.

D. Sander-Football cleats were pushed with a constant force against the belt of a wet sander.

E. Loss related to loss of "Zytel" 101 which is defined as unity.

TABLE III
Coefficient of Friction of "Delrin" on Steel

	Coefficient of Friction* Static	Dynamic
Dry (73°F.)	0.1-0.3	0.1-0.3
Dry (250°F.)	0.1-0.3	0.1-0.3
Lubricated with water (73°F.)	0.2	0.2
Lubricated with oil (73°F.)	0.1	0.05-0.1

*Measurements were made by the inclined plane method.

TABLE IV
Electrical Properties

	Reagent	Value
Dielectric strength, short time	D-149	500 V/mil
Volume resistivity	D-257	6×10^{16} ohm/cm. (0.2% water) 4.6×10^{13} (0.9% water)
Surface resistivity	D-257	2×10^{15} ohm
Arc resistance	D-495	129 seconds (burns)
Dielectric constant, 73°F.	D-150	10^2 CPS — 3.7 10^3 CPS — 3.7 10^4 CPS — 3.7
Dissipation factor 73°F.	D-150	10^2 CPS — 0.004 10^3 CPS — 0.004 10^4 CPS — 0.004

TABLE V
Resistance to Organic Chemicals

Reagent	% Change in 12 Months					
	Tensile strength		Weight		Length	
	Room Temp.	158°F.	Room Temp.	158°F.	Room Temp.	158°F.
50% Igepal	+2	—58	—1.8	+0.1	+0.05	—1.21
"Nujol"	+1	+2	+0.3	—0.5	—0.08	—0.37
"Unifio" motor oil 10W30	. .	+3	. .	—0.2	. .	—0.30
Carbon tetrachloride	—3	—7*	+1.2	+5.7*	+0.30	—0.25*
100% Ethyl alcohol	—5	—5*	+2.2	+1.9*	+0.81	+1.00*
Acetone	—5	—7*	+4.9	+2.6*	+0.91	+1.08*
5% Acetic Acid	0	—8*	+0.8	—2.6*	+0.15	—0.22*
Toluene	7	—7*	+2.6	+2.8*	+1.20	+1.20*
"Super 9" brake fluid	. .	—6	. .	+1.6	. .	+0.57
"Lockheed" 21 brake fluid	. .	—23	. .	+0.9	. .	+0.29
Ethyl acetate	—7	—7*	+2.7	+2.9*	+1.35	+1.10*

*Because of difficulties in carrying out the test these samples were tested at 122°F. instead of the higher temperature.

Test Conditions:

1. Bars were completely immersed in solvent for time indicated.
2. Tests were made by standard ASTM procedures at room temperature immediately after removal from solvents.

TABLE VI
Resistance to Inorganic Chemicals

Reagent	% Change in 6 Months					
	Tensile strength		Weight		Length	
	Room Temp.	158°F.	Room Temp.	158°F.	Room Temp.	158°F.
30% Sulfuric Acid	>—30	. .	—48	. .	. .	. .
10% Nitric Acid	—>30	. .	—70	. .	—1.00	. .
10% Hydrochloric Acid	—>30	. .	—84	. .	—1.91	. .
10% Sodium Hydroxide	0.0	. .	+0.01	1	+0.02	. .
10% Sodium Chloride	0.0	+ 1.0	+0.05	+0.02	+0.01	0.00
Buffer soln., PH4	. .	—>60	. .	—>20	. .	. .
Buffer Soln., pH7	. .	— 1.0	. .	— 0.05	. .	—0.22
Buffer soln., pH10	. .	— 3.2	. .	— 0.83	. .	+0.02

Test Conditions:

1. Bars were completely immersed in solvent for time indicated.
2. Tests were made by standard ASTM procedures at room temperature immediately after removal from solvents.

TABLE VII
Permeability by Organic Liquids

Liquid	"DELRIN"		Regular Polyethylene	Linear Polyethylene
	Loss/yr. (Grams)	P. Factor*	P. Factor*	P. Factor*
Methyl salicylate	0.51	0.27	9.1	2.0
Toluene	1.28	0.65	666.0	150.0
Turpentine	0.04	0.023	47.0	3.0
Methanol	. .	. .	3.6	0.4
Ethanol	0.40	0.22	. .	. .
Water	7.7	3.0	0.35	. .
"Perclene" (chlorinated hydrocarbon)	0.40	0.23	. .	. .
"Freon" 12/114	0.6	0.33	. .	. .

Test Conditions:

Containers: Sealed 4 oz. Boston Round bottles, blow molded, 35 mils thick.

Temperature: 73°F.
Humidity 50% R.H.

*P-Factor is defined as the grams lost per 24 hours per 100 sq. in. area per mil of wall thickness. This factor allows the calculation of the loss that can be expected from any given bottle.

TABLE VIII
Design Characteristics

Stiffness
Resistance to creep
Tensile strength
Abrasion resistance
Low coefficient of friction
Fatigue endurance
Toughness
Dimensional stability
Chemical and solvent resistance
Retention of properties in adverse environments
High gloss
Colorability

Electrical Properties

Superpolyoxymethylene is one of the few materials that combine excellent electrical properties with exceptional mechanical characteristics (Table IV). It has remarkably low dissipation factor and dielectric constant over a wide range of frequencies at both room and elevated temperatures. The volume resistivity is high and not appreciably changed with increasing humidity because of low moisture absorption. As a result of this low moisture absorption, the polymer maintains its other good electrical properties under high humidity exposure and after complete immersion in water.

In the majority of electrical uses, mechanical properties are of more importance than electrical properties. This resin should prove to be an ideal insulator for applications where good electrical properties are required in conjunction with high strength, abrasion resistance, solvent resistance, dimensional stability, and retention of properties at high temperatures.

Chemical Resistance

Superpolyoxymethylene is unusual among thermoplastics in its resistance to organic solvents. There are no common solvents for it at low temperatures. Table V lists the changes in weight, length, and tensile strength of bars after they were exposed for twelve months to various organic materials. Excellent strain resistance is a natural complement to the superior solvent resistance of the polymer. Tests have shown it to be unaffected after constant exposure at room temperature for one week to a wide variety of common and usually troublesome substances like tea, catsup, vinegar, vegetable dies, oleomargarine, lemon juice, beet juice, and lipstick. Mustard and a kiss-proof lipstick caused slight discoloration in the above test. Table VI shows the same type of data after six months of exposure to typical inorganic materials. It is not recommended for use in contact with strong acids or strong bases. For applications in which weaker acids or bases are involved, it is recommended that tests be made under actual service conditions to determine the suitability of the resin for the particular environment.

The permeability of this polyoxymethylene (Table VII) has been found to be a fraction of that of polyethylene when exposed to aliphatic and aromatic hydrocarbons, halogenated hydrocarbons, alcohols and esters, which makes it an excellent candidate for packaging applications. Its permeability to water vapor is significantly more than that of polyethylene.

There is no significant decrease in the physical properties upon prolonged exposure to air in continuous service at temperatures up to 180°F. or in intermittent service at temperatures up to 250°F. In water, there is no significant loss of physical properties upon continuous exposure at temperatures up to 150°F. Sufficient data yielding meaningfully higher service temperature limits for continuous service are not yet available. However, parts have been autoclaved for one hundred 15-minute cycles in 250° steam without significant loss in strength or toughness. In one test a sample of 1" pipe has performed successfully for over 21 months in continuous exposure to water at 145°F. and 68 psi. The polymer has been immersed in motor oil at 212°F. for 2,000 hours with no significant change in physical properties.

Polyoxymethylene like most other polymers, is affected by ultra-violet light and should be filled with small amounts of well dispersed carbon black it if is to be exposed out of doors. Although present colored compositions retain their properties fairly well, they tend to chalk

and can be rated only fair in weatherability. Tests have shown no loss of properties when buried underground, nor to any attack by fungi, rodents, or insects.

Miscellaneous Properties

The natural polymer is an opaque white which makes possible an unlimited number of colored compositions. Colorability is excellent in that the colored products have a sparkle and brilliance beyond that produced by the coloring alone. This quality may well be the result of the very high crystallinity of the material.

The polymer burns slowly when ignited. By the ASTM standard burning rate test, it burns at about the same rate as other familiar thermoplastics such as polyethylene, polystyrene, acrylic resins, and cellulose acetate butyrate, all of which are classified as slow burning.

Extensive data show that this acetal resin presents no toxicity hazard when used for dishware, coffee cups, and other common household utensils. Preliminary feeding tests, in which rats were fed 5,000 mg/kg/day of "Delrin" for five days a week for two weeks, resulted in no damage to the organs of any of the rats. Apparently, it is nontoxic when taken orally. However, it should not be used for packaging food, as prior approval must be obtained from the Food and Drug Administration.

END-USE TESTING

Basic property data showed the combination of end-use characteristics which the acetal resin exhibited, (Table VIII). Using these inherent product properties as a foundation, the areas of greatest possible use had to be established. Knowing that simple qualitative prediction of possible end-use areas did not provide ample reliability, two techniques were devised to define adequately the specific end-use areas for the new polymer (Table IX).

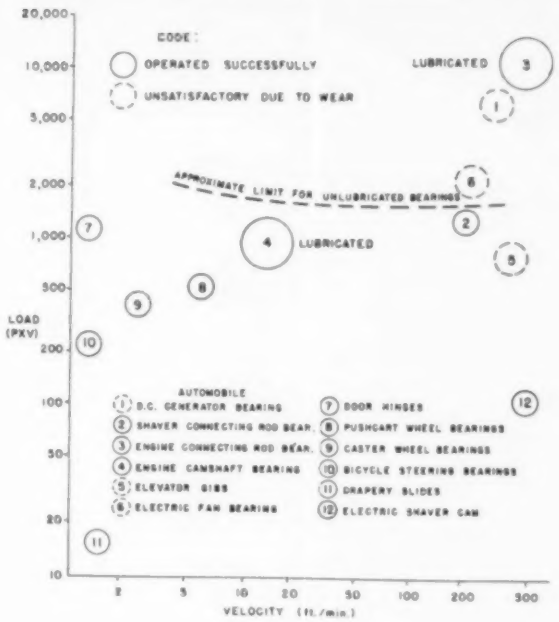
The first was the running of an extensive end-use test program on specific applications in actual or simulated service—all the time accumulating more and more data on product performance and processing know-how. The second technique was the proving of projected applications by showing through actual calculations that a part of the new material was technically and economically suitable for the use under study. A design handbook on the acetal resin was useful in making the design calculations.

Selection of an end use for inclusion in the testing program was based upon two things. First, the use must require, for satisfactory performance, one or more of the significant properties of the polymer. Second, the test part must be capable of being produced by standard machining or thermoplastic processing techniques. Items for testing were fabricated from a limited polymer supply using various techniques: machining from rods and plaques, extrusion from new or existing dies, and molding in new temporary cavities for acetal resin or in existing molds for other thermoplastics. A novel and successful approach was the use of die casting molds to injection mold parts for testing.

Aerosol Containers

The evaluation of this linear acetal resin as an aerosol container in the packaging field illustrates the kind of thinking that went into the selection of end uses for testing and the tests to be run. Initial processing studies showed that blow molding of containers was feasible. In order to perform satisfactorily, aerosol containers require a combination of many properties like tensile strength, stiffness, toughness, low creep, chemical resistance, and low permeability plus colorability and high gloss for decorative appeal. Since these are all strong points of the polymer, tests on blow molded aerosol containers had a high chance of success and would confirm many properties in one evaluation.

Figure 13. Bearings of Acetal Resin Are Promising.



In the evaluation a number of two-ounce containers (wall thickness approximately 0.045") were loaded with two aerosol formulations—a cologne and a shaving lather —using a fluorinated hydrocarbon propellant. After more than a year at room temperature the bottles showed no bulging or other distortion and still contained enough propellant completely to discharge the contents. In a vigorous accelerated test at 130°F. for three months, similar bottles with the same formulations showed some weight loss, but the contents were still completely dischargeable. Twenty-five bottles were filled with a fluorinated hydrocarbon propellant and dropped once from a height of 11 feet with none of the bottles breaking.

Plumbing Fixtures

An evaluation of some end-use was needed which required the dimensional stability of the polymer in the presence of water at elevated temperatures. It was soon determined that such tests could best be made on plumbing fixtures.

A five-part showerhead machined from the resin and having standard pipe threads was used in normal household service for twenty-one months with no evidence of failure. In a laboratory test, water at 150°F. was run continuously through the showerhead for eighty-eight days. Extrapolation of these accelerated test data indicates a service life of at least twenty years in normal use. At the end of both of these tests, the threads of the used male section still meshed perfectly with the threads of an unused female section, and the spray pattern remained unchanged. This evaluation substantiated basic property data on the low creep rate and the small effect of moisture on dimensions even at elevated temperatures.

Figure 14. Gear Test Results.

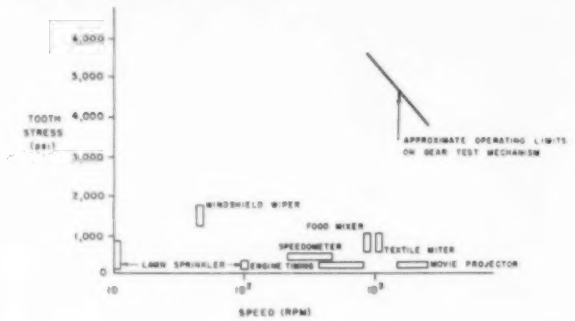
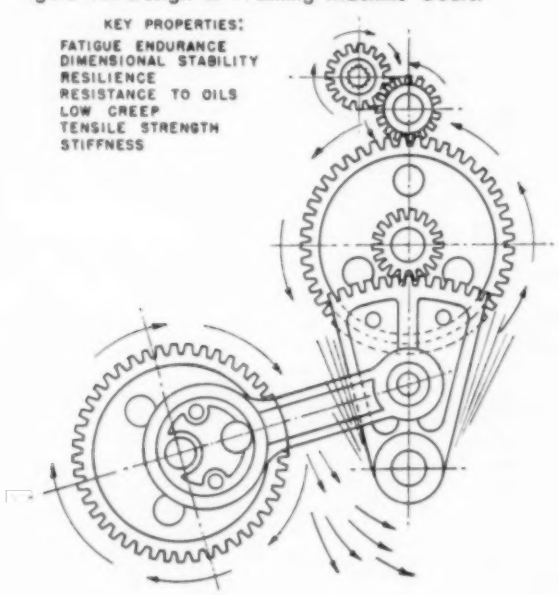


Figure 15. Design of Washing Machine Gears.



Bearings

Fundamental property data indicated that this linear acetal resin would function as an excellent bearing material because of its low coefficient of friction, absence of slip-stick tendencies, low creep and dimensional stability under adverse environmental conditions. The good results of simulated bearing tests were not considered to be sufficient proof of the suitability of the polymer for bearings.

Therefore, a great many bearings, both machined and/or molded, were tested in actual end uses under a wide variety of load and speed conditions and with varying degrees of lubrication (Figure 13). These tests confirmed the suitability for unlubricated bearings, particularly at high loads and low speeds, and the improved operating characteristics of lubricated bearings.

Some of the bearings tested were rated as unsuccessful because of wear, although the operating characteristics of the complete assembly were satisfactory. When the polymer does wear, it wears uniformly and the wear particles are discharged from the bearing area.

One of the most interesting bearing tests was the split type connecting rod bearing for a 3/4 horsepower gasoline engine. During the test the temperatures were running around 170°F. although the operating temperature went as high as 250°F. at times. The bearing was operating under a load of 20 psi at a surface velocity of 400 to 500 feet/minute. When the test was discontinued after 70 hours, the bearing showed no sign of deformation or wear.

Gears

Acetal resin should perform satisfactorily as a gear material because of its good combination of desirable gear properties. The approach used to confirm this was the running of a number of practical gear applications in actual service (Figure 14). In addition, more data were obtained from runs on a gear testing machine.

As can be seen from the diagonal line at the upper righthand corner of Figure 14, the load speed conditions for acetal gears are fairly broad.

Two gear applications, in particular, show the ability to operate satisfactorily at elevated temperatures. Drive gears in an electric windshield wiper were operated continuously for more than 1700 hours at 150°F. and 7 inch-pounds of torque with essentially no wear. The combination engine timing gear and cam shaft of a 3/4 horsepower gasoline engine showed no signs of wear or deformation when the test was discontinued at the end of 70 hours during which the average oil temperature was 170°F. and at times went as high as 250°F.

Two other gear applications, in addition to showing the suitability of the polymer for the use, confirmed its dimensional stability in the presence of moisture. Water sprinkler gears have functioned perfectly without jamming during two summers' operation. A fine pitch gear for a movie projector did not jam during a hot humid summer while, under like conditions, the same gear jammed when made from other thermoplastics.

Projected Applications

Knowledge of the fundamental property data on this acetal resin coupled with our experience with specific end-use tests make it possible to predict representative future uses. To further the design of mechanical parts, studies have been carried out to determine whether or not the classical engineering formulas which have been used with metals will fit this new polymer. A number of plate and beam formulas for determining deflection have been checked. Tests have been made on the effect of shape and cross section, distribution of weight, and the way the piece was supported. Results show that the behavior of superpolyoxymethylene can be calculated with assurance through use of known fundamental data on the material. For example, by substitution of the time dependent modulus into the standard beam equation a calculated deflection after any given time was determined. This was in excellent agreement with the actual measured deflection.

Using design information of this type in conjunction with a knowledge of the end-use requirements of a specific application, studies were made to determine suitable projected applications for the new material. In order to define further the size of the market for this material, a number of these projected applications were calculated.

One such application studied was that of washing machine gears for agitator washers. These gears are found in the transmission of automatic washing machines and seem to offer an excellent opportunity for the polymer. The existing steel gears are noisy, costly, and add considerable weight to the machine. Although no plastic

has yet been able to meet the requirements for these parts, the new resin should have no difficulty in this application because of its high temperature stiffness, high fatigue endurance limit, and resistance to oils and greases. In addition, its quietness of operation would be a decided asset. Figure 15 shows a schematic diagram of these gears along with the key property requirements. Engineering design calculations have been made on these gears along with cost calculations and show that "Delrin" will not only be technically satisfactory but will cost less than the machined steel gears because of the economics of injection molding. Similar calculations on automotive carburetors, sewing machine housings, squirrel cage blowers, automotive window crank handles and door knobs, and wash basin drain assemblies show that the resin meets all of the necessary design requirements for these end-uses and offers potential cost savings.

PROCESSING

We have molded "Delrin" in a large number of machines both at our Sales Service Laboratory and in our field evaluations. During this time we have used machines made by about 10 different molding machine manufacturers and ranging in size from 1 oz. to 60 oz. We have also used quite a variety of molds—single cavity temporary molds, die casting molds, molds with cam-action, production molds designed for other materials, molds having hydraulic core pulls, and multi-cavity molds up to 100 cavities with excellent results. Performance has been satisfactory in fully automatic injection machines using multi-cavity molds.

The polymer has also been run in a variety of different extruders, ranging in size from 1" to 4-½". We have made such things as sheet, pipe, rods, tubing and blow molded bottles using conventional techniques.

Since this linear acetal resin is a new type of thermoplastic material, it might be well to take a look at its melt viscosity in relation to some of the thermoplastics more widely used now. Figure 16 shows a graph of the apparent melt viscosity of several thermoplastics as a function of temperature. In the high viscosity ranges we have 150X, which has been specifically designed as an extrusion material. Its melt viscosity is in the same range as Lucite® 140 and Zytel® 42. In the molding range we have 500X which is quite comparable in melt viscosity to Alathon® 14. The slopes of the lines in this graph give a measure of the effect of temperature on the melt viscosity of the different materials. The steeper the slope, the greater the effect of temperature on melt viscosity. Neither 150X nor 500X shows the change in melt viscosity with temperature that is shown by materials like the acrylics and polyamides. Thus, with this polymer we do not get the sudden decrease in melt viscosity with increasing temperature that we do with some other materials.

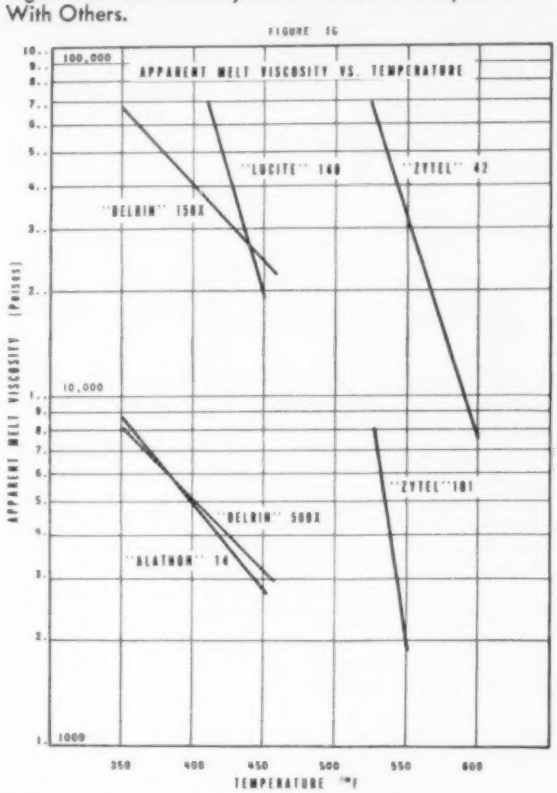
Drying of the virgin material prior to either extrusion or molding is not a critical factor and if it is necessary standard equipment and techniques are suitable.

Molding

Since this is a new type of thermoplastic material the molding and extrusion techniques will be covered in some detail.

The polymer has been molded in essentially every type of conventional injection molding machine manufactured in the United States. However, the quality and dimensional accuracy of the molded pieces are governed to a very large extent by the characteristics of the particular molding equipment used. No special materials of construction are required for the cylinder. Based on our

Figure 16. Melt Viscosity of Acetal Resin Compared With Others.



experience cylinders in reasonably good condition are suitable for molding the resin.

Standard molding machine spreaders or torpedos are quite satisfactory for processing the polymer. As with any material, care should always be taken that the spreader be seated properly in the cylinder so that there is no possibility of localized hold-up and consequent decomposition of the polymer. An experience in the laboratory illustrates this quite well. In a 3 oz. horizontal machine after a few hours yellow streaks were noted in the molded parts. This was indicative of a point of localized hold-up in the machine and molding was stopped and the heating cylinder dismantled. It was found that the torpedo did not seat properly at the nozzle end of the cylinder and formed a small pocket of static material. By machining the torpedo to the proper fit any further difficulties with that cylinder were eliminated.

The nozzle we suggest is the reverse taper nozzle or, as it is sometimes called, the nylon nozzle (Figure 17). Satis-

Figure 17. The "Nylon" Nozzle Works Well for Molding Acetal Polymer.

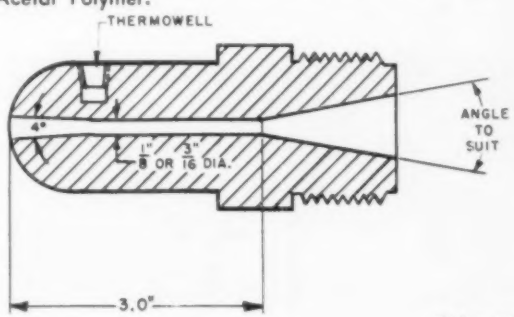


Figure 18. "Through-put" Values for Acetal Polymer.

THROUGH-PUT AS A FUNCTION OF MACHINE CAPACITY AND SHOT SIZE. TYPICAL CASE HISTORIES COVERING A VARIETY OF MOLDS.

MACHINE Rated Capacity (oz.)	SHOT SIZE (oz.)	THROUGH-PUT pph
2	1.3	5.8
3	2.4	9.5
4	2.5	17.0
8	6	22
12	8.2	36
16	15	32
24	17	50

THESE THROUGH-PUTS WERE OBTAINED FROM ACTUAL MOLDINGS AND DO NOT REPRESENT MAXIMUM MACHINE OUTPUT

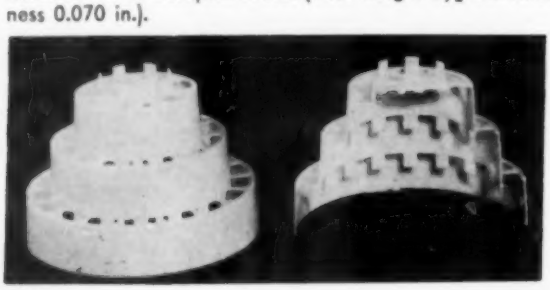
factory molding has been done with conventional straight bore nozzles or with converging bore nozzles, with little difficulty. However, in certain molding machines, particularly the vertical machines, there is less tendency for drooling with the reverse taper nozzle. We do suggest that the nozzle be equipped with a heater band capable of maintaining a temperature of at least 410°F. This is quite necessary for machine start-up and prevents nozzle freeze-offs in case of any undue cycle delays.

Normally, the polymer should be molded at controlled temperatures of 390°F to 440°F. Temperatures, of course, will depend on the quantity of material in the shot, the design of the cylinder, and the ease of mold filling. Higher temperatures, for instance 415 to 440°F, will generally be required on moldings of thin sections produced at high rates. For example, a 9 oz. shot in a 12 oz. machine on a two minute cycle might be molded at 400 to 415°F. However, a 3 oz. shot in the same machine on a 30 second cycle would probably be molded better at temperatures around 430°F.

Higher temperatures than those advised above will not increase the flow characteristics significantly because of the melt viscosity versus temperature relationship of the material (Figure 16). Therefore, if there are mold filling difficulties encountered at these temperatures other changes, such as increasing the mold temperature or enlarging the gates and runner system, may be necessary.

The best way of monitoring the nominal molding temperatures is by reading the actual stock temperature which for this acetal resin should normally be 400°F. A stock thermocouple, properly designed so that it will not cause a localized polymer hold-up, can be invaluable for constant monitoring. Readings can also be taken from an air shot using a needle probe indicating pyrometer. We have used this latter method quite frequently in our field evaluation work.

Figure 19. This Difficult Part Shows Ability of Acetal Resin to Fill a Complex Mold. (Shot weight 6½ oz. Thickness 0.070 in.).



The cycles required for molding the polymer can be estimated on the basis of about 1 minute overall cycle per 1/4 inch of thickness. Following this generalized rule, a 1/8 inch section will require a cycle of about 30 seconds and a 1/2 inch section, about 2 minutes. Articles with non-uniform cross-sections whose edges or surfaces must be extremely flat or straight, may require longer cycles.

The through-put of an injection molding machine is another way of expressing cycle. Figure 18 shows the through-put in pounds per hour as a function of rated machine capacity. This through-put is taken as conversion to molded parts, and thus could not be completely divorced from the mold being used.

Molds and Mold Designs

Most molds suitable for use with other thermoplastics are suitable for acetal resin. They may either be hard or soft steel and need not have chrome plated surfaces except where very high finishes are desired. They should be so designed that a clamping pressure of at least 5 tons per square inch of projected area can be exerted on the mold during the injection stroke.

Close control of mold temperature is important in the molding of high quality parts which require the optimum combination of physical properties and dimensional controls, but for routine molding standard equipment and coring are satisfactory. To obtain close control of mold temperature the mold must be cored to permit circulation of a suitable heat transfer fluid. To provide zone control, multiple independent coring may be required. The equipment must be provided for controlling the temperature of the circulating fluid automatically so that the mold can be held at any temperature between 150 and 250°F. In moldings where optimum surface gloss is desired it probably will be necessary to use molds in the higher end of the temperature range. However, in most moldings very good surface gloss is obtained using mold temperatures of 150°F to 170°F.

In general, runners should be between 1/8 and 3/8 inch diameter. For articles having a wall thickness of 1/8 inch or less and in relatively easy to fill cavities, runners of 1/8 inch should be satisfactory. For articles having heavier wall thicknesses, the diameter of the runner should be 1/2 to 2/3 the thickness of the article being molded but need not exceed 3/8 of an inch. The runners and gates to each cavity in a mold should be uniform in thickness even if the cavities are not, as in a family mold. They should have parallel smooth walls and be as short as possible. The gates should be blended into the cavity with a generous radius and be so located that the injected material will impinge directly on an opposing face or insert pin where possible. This will decrease the likelihood of the formation of surface imperfections in the vicinity of the gate. Conventional gating used for other materials has proven quite satisfactory for use with this polymer. Three-plate molds with gates as small as 0.040" have given satisfactory performance. In certain molds submarine gates have been used with excellent results.

The ability to fill a relatively difficult mold can be illustrated by the part shown in Figure 19. This mold was originally designed for use with polystyrene and these shots were made with no mold alterations. A look at the illustration will show that not only is good flow needed for a shot of this type but also the ability to form a good weld. Tensile measurements of the weld indicate that they average about 96% of the strength of a standard specimen. Since this part has 35 weld lines, it shows

that this acetal resin will form good welds when properly processed.

The ejection of molded parts from the mold cavities is excellent. For example we have molded in a 40 cavity bearing mold. The bearings were 1" long and even though there was no internal or external taper the ejection was excellent. In the molding work that we have done we have not encountered any problems at all with ejection, and this includes unscrewing of parts from the mold.

The design of a mold cavity for use with this polymer follows the same procedure as that for any other thermoplastic. However, since this resin is a crystalline material, the mold shrinkage and dimensional change on annealing will usually be greater than that obtained with an amorphous material. In the design of a mold to make a part of a particular dimension, there are three factors which must be considered. These are mold shrinkage, dimensional changes caused by annealing, and dimensional changes resulting from exposure to different environments. As mentioned before the polymer has outstanding dimensional stability, but in designing mold cavities for parts that require close tolerances, small changes in dimensions that might occur should be considered.

Mold shrinkage results from a decrease in volume when the molten material in the mold cavity solidifies. For a given mold under the same molding conditions this amount of shrinkage will be constant. However, since it is not possible to operate a molding machine so that every shot is identical to every other shot, there will be small fluctuations in the absolute dimension from part to part.

Molds for articles whose specific dimensions are not critical can be designed by allowing for shrinkage in the range 0.010" to 0.035" per inch of linear dimension. For shots whose dimensions are critical a more careful analysis of shrinkage must be made.

A procedure used in achieving the correct cavity dimensions consists of the following steps.

1. **Machine a trial cavity based on mold shrinkage.** Annealing shrinkage and dimensional changes due to environment also should be considered if the part is to be annealed and/or subjected to environmental conditions like moisture and elevated temperatures.

   Changes in dimension caused by annealing are usually in the range of 0.001 to 0.004 inches per inch. If the value of 0.002 inch per inch is used any additional correction can usually be done by slight changes in molding conditions.

   The changes in dimensions caused by water absorption and/or temperature changes usually can be predicted quite accurately from Figure 12. These data indicate the allowances which should be made in designing the mold cavity.
2. **Mold parts in trial cavity and measure dimensions.** If annealing and water conditioning is to be done on final parts then they should be done prior to measuring.
3. **Based on results of step 2, adjust cavity dimensions to give part of desired dimensions.**

The first application of this procedure to the design of a test mold for acetal resin is discussed here. The mold was for a single cavity sprue-gated disc having a thickness of 0.200" and a diameter of 3.056".

Hypothetically it was assumed that the parts were to be annealed and soaked in water. These conditions were chosen to test the ability to mold parts to close tolerances when annealing and moisture conditioning were required post molding operations. Table X illustrates the processes gone through to design a mold to give the desired dimension. The first trial cavity dimensions were calculated by using estimates of shrinkages obtained

TABLE IX
Partial List of Indicated Suitable Uses

Mechanical

Pressure gage gears
Water sprinkler gears
Textile pinion and meter gears
Movie projector gears
Lathe bed carriage racks
Bicycle thrust bearings
Lawn mower roller bearings
Sickle mower sleeve bearings
Actuator cams, business machines
Drawing compass spring
Sprayer nozzles and discs
Portable gasoline engine
  Connecting rod bearings
  Crankshaft bearings
  Timing gears
  Timing cams

Plumbing & Hardware

Showerheads
Toilet flush valves
Drawer handles
Chair glides
Drapery slides
Butt hinges
Chair caster wheels
Cart wheels

Appliances

Refrigerator door latch rollers
Ice tray separators
Freezer compartment hinges
Food mixer gears
Dishwasher support fingers
Electric shaver cam followers

Automotive

Electric windshield wiper gears
Vacuum windshield wiper valves
Door latch rollers & wedges
Gasoline fuel filter caps
Gear shift knobs
Speedometer takeoff gears
Door hinge bushings
Steering gear bushings
Brake pedal bushings

Consumer

Tableware
Tumblers
Knife handles
Fountain pen barrels
Combs
Pipe stems
Clothespins
Soap dishes
Brush handles
Football shoe cleats
Toys

Packaging

Aerosol bottles

TABLE X
Design of Cavity for Precision Molding

	in/in	Total	
FIRST TRIAL CAVITY			
Desired Part Diameter			3.056 ± .001
Allow for Mold Shrinkage	.024	—.072	
Allow for Annealing Shrinkage	.003	—.010	
Allow for Water Absorption	.003	±.009	
TOTAL ALLOWANCE		0.071	.071
Test Cavity Diameter			3.127
Molded Part			3.019
Part Undersized			.037
MODIFIED CAVITY			
Desired Part Diameter			3.056
	in/in	Total	
Mold Shrinkage	.035	—.105	
Annealing	.004	—.012	
Water Absorption	.003	±.009	
TOTAL ALLOWANCE		0.108	.108
Cavity Diameter			3.164
Molded Part			3.055

Figure 20. Shrinkage Pressure of Moldings Depends on Injection Pressure and Part Size. (5" x 1/2" x 1/4").

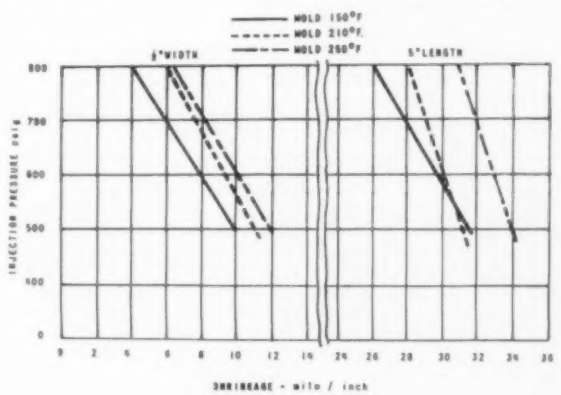
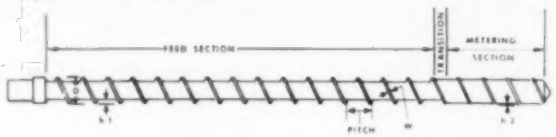


Figure 21. Metering Screw Dimensions Suggested for Extrusion of Acetal Resin.



SUGGESTED DIMENSIONS FOR "DELRIN" 150X

DIAMETER (D), INCHES	PITCH (P), INCHES	DEPTH OF FEED SECTION (h_1), INCH	DEPTH OF METERING SECTION (h_2), INCH	WIDTH OF LAND (W), INCH
1-½	1-½	0.250	0.085	0.150
2	2	0.330	0.110	0.200
2-½	2-½	0.420	0.140	0.250
3-½	3-½	0.550	0.185	0.325
3-½	3-½	0.600	0.200	0.350
4-½	4-½	0.750	0.250	0.450

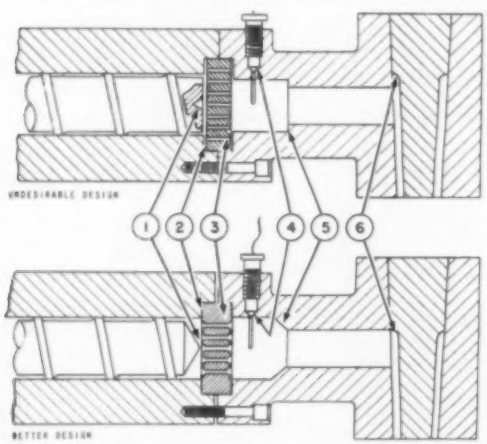
from other moldings and we estimated on the low side in order to allow machining of the cavity to the final dimensions.

It should be pointed out that this procedure is suggested only for very close tolerance molding work. In most of the applications sufficiently accurate calculations can be used to arrive at satisfactory mold dimensions.

With molding equipment in good operating condition it is usually possible to mold a particular dimension to about ± 2 mils per inch of linear dimension. However, if the molding operation is controlled very carefully it is possible to mold to much closer tolerances. For example, in the part discussed above we were able to hold the 3.055 dimension to ± 0.0021 for 99.7% of the parts (3σ limits). This variation is for the entire diameter and if quoted on an inch per inch basis the variation would be ± 0.0007 in/in. This illustrates what can be done in the way of close tolerance molding but, it should be repeated, that very close control of the molding operation is necessary to attain a figure as small as this.

As we are all aware, molding conditions can have a pronounced effect on the mold shrinkage and thus on the final part dimension. The effect of certain molding variables on mold shrinkage is shown in Figure 20, where there is plotted mold shrinkage in inches per inch as a function of the injection pressure at different mold temperatures. The mold used was an end-gated test bar mold, 5″ x ½″ x ¼″. Minimum mold shrinkage of about 0.025″ per inch was obtained using high injection pressure and low mold temperature. The maximum mold shrinkage of about 0.032″ per inch was observed at low injection pressure and a hot mold.

Figure 22. Common Design Features Which Can Lead to Localized "Hold-up" Areas and Difficulties.



1. SCREW CENTERING HOLES SHOULD BE FILLED OR ELIMINATED.
2. BREAKER PLATES SHOULD FIT TIGHT AND ACT AS SEALING SURFACES.
3. THERE SHOULD BE NO DEAD HOLES IN THE BREAKER PLATE.
4. STOCK THERMOCOUPLES SHOULD SEAT PROPERLY AND DEAD SPACE SHOULD BE ELIMINATED.
5. SHOULDERS SHOULD BE STREAMLINED.
6. THE MANDREL SHOULD MEET IN THE CROSSHEAD PROPERLY AND DEAD SPACE ELIMINATED

Extrusion

"Delrin" has been extruded into a variety of shapes and forms. Rod of various diameters can be readily extruded. Pipe and tubing of various diameters and wall thicknesses have been extruded by several techniques. Several shapes of blow molded bottles can also be prepared. Sheet extrusion and wire coating can be done readily using present commercial equipment. The polymer has been successfully processed in a large variety of extruders with respect to both design and size. No special design consideration is necessary for extrusion and no special materials for construction are required. But for the best results the extrusion equipment should incorporrate the following features which are in keeping with the present day extrusion practice.

For the extrusion of the material we recommend that long barrels be used. Barrels with high ratios of length to diameter (20:1) are advantageous because they increase the available heat transfer area in the machine and provide a wider range of thru-put rates and a more homogeneous melt temperature distribution.

Either electrical heating or oil heating may be used on barrels of extruders for processing the polymer. The barrel should be heated in several independently controlled heating zones, usually 3 to 4 zones. The temperature of each zone should be regulated by its own thermocouple in the controlling instrument.

The temperature measured by these thermocouples is actually the temperature of the heated barrel and often varies widely from that of the melt. The temperature of the melt is a critical factor influencing the behavior of the polymer in the die and on the take-off. To measure this temperature, the stock thermocouple, such as the one described in the paper by Bernhardt, (Ref. 1) should be inserted in the melt stream just beyond the breaker plate and this thermocouple should be well insulated from the metal barrel wall.

A metering type screw as shown in Figure 21 is recommended for the extrusion of acetal resin. It is a constant pitch screw divided essentially into two sections, feed section and metering section.

The feed section is the zone of the screw that picks up the solid resin particles and conveys them forward through the heated extruder barrel. The feed section has the deepest channel and the highest conveying capacity of any zone along the length of the screw. Since the feed section is followed by a zone of lower conveying capacity the pressure in the resin gradually increases along the length of the feed section.

The metering section normally comprises the last four flights along the screw and has a shallower channel. It is characterized by the fact that channel depth, pitch and land width do not change along this length. This uniform geometry gives all the flights of the metering section identical delivery characteristics and helps assure a predictable and surge free delivery. The dimensions shown in Figure 21 are suggested for extruder screws to be used with "Delrin" 150X. These dimensions are for average

(Please turn to Page 68)

U.S.I. POLYETHYLENE NEWS

A series for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

Packaging Notes

Sealed Polyethylene Box Liners for apples have been found to eliminate weight loss, retard ripening and reduce scald of apples held in cold storage. Sealed liners were found to be superior to coated paperboard liners and unsealed liners for most varieties of apples tested. Research showed, however, that quality and uniformity of the film used played an important part in its effectiveness in lengthening apple storage life.

Poly Film to be Featured at National Packaging Exposition in New York, May 26-30. U.S.I. will introduce at the show a new polyethylene film of unprecedented clarity. The broad range of PETROTHENE polyethylene resins expressly developed by U.S.I. for packaging applications will also be demonstrated.

The show, sponsored by the American Management Association, is expected to attract more than 40,000 visitors. Exhibits will feature the latest in packaging machinery, materials and design. Technical sessions will also be held.

Theme of the U.S.I. exhibit at the show will be "PETROTHENE Polyethylene for clear, tough, protective film." U.S.I. Technical Service engineers will be on hand to answer questions on film processing and applications. Packagers and others interested in using polyethylene film can see extraordinary film clarity and toughness demonstrated at the U.S.I. exhibit. (Booth nos. 221, 225, 322 and 326 on the fourth floor of the N. Y. Coliseum.)

New York Coliseum, site of the 27th Annual National Exposition at which U.S.I. will introduce film made from its new high clarity polyethylene.

New Heat Seal Booklet discusses the factors involved in obtaining satisfactory heat seals on polyethylene film. The 16 page booklet is illustrated with 40 graphs showing how time, temperature, melt index, slip agents and resin density affect heat sealing. Heat seal characteristics are given for various resins in U.S.I.'s PETROTHENE polyethylene resin series. Copies of the booklet are available without charge to extruders, convertors and packagers. Write to U.S.I. for "Heat Seal Characteristics of Polyethylene Film."

New U.S.I. Plant Will Produce 75,000,000 lbs. of Polyethylene a Year

Houston Facility Scheduled for Completion Next Winter

A second plant to produce U.S.I. PETROTHENE® polyethylene is scheduled to go on stream next winter in Houston. Capacity of the plant—75,000,000 pounds per year of intermediate density polyethylene resins—will almost double U.S.I.'s present polyethylene capacity. The plant at Tuscola, Ill., now has a 100,000,000 pound-per-year capacity.

Site for the new plant was selected to meet two prime considerations—easily accessible transportation for fast customer service, and a dependable supply of quality raw materials.

The 200 acre site on the Houston Ship Canal provides both. Shipments will be made by rail and truck, with the port facilities of Houston available for export orders. High purity ethylene will be piped in from nearby existing facilities of The Phillips Petroleum Company. Phillips will also supply the natural gas requirements of the plant.

The new installation will use a modification of the conventional high-pressure process, already proved in the Tuscola plant. Intermediate density resins will be produced, with properties somewhere between those of the original polyethylene resins and the new high-density resins produced by low-pressure processes.

National Petro-Chemicals is presently the third largest polyethylene producer in the United States. Petro has quadrupled PETROTHENE capacity in the past three years.

PETROTHENE polyethylene plant at Tuscola, Ill.

U.S.I. Assumes Full Control of National Petro-Chemicals

Full stock ownership of National Petro-Chemicals Corporation, producer of PETROTHENE polyethylene resins, has been acquired by U.S.I.'s parent company, National Distillers and Chemical Corp., from Panhandle Eastern Pipeline Company.

National Petro-Chemicals has been majority owned and managed by U.S.I. since its founding.

Saran-Coated Polyethylene Film Offers Improved Clarity, Lower Permeability

A recent evaluation of saran-coated polyethylene film indicates that as little as 0.1 mil of saran coated or laminated to polyethylene film gives improved clarity to the film and greatly increases its impermeability to oils, organic liquids and gases.

This latter property, especially, promises to open up new packaging applications to coated polyethylene film. It permits the packaging of such foods as processed meats and cheeses in either a vacuum or inert gases, and helps retard oxygen-caused rancidity and discoloration in packages containing fats, oils, dried whole milk and many other products. Reduced permeability to organic liquids and vapors would enable the film to increase the shelf life of pharmaceutical products and furnish better protection against off-taste and contamination.

The tests showed that similarly good results can be obtained with saran-coated polyethylene bottles and collapsible tubes.

IN THIS ISSUE:

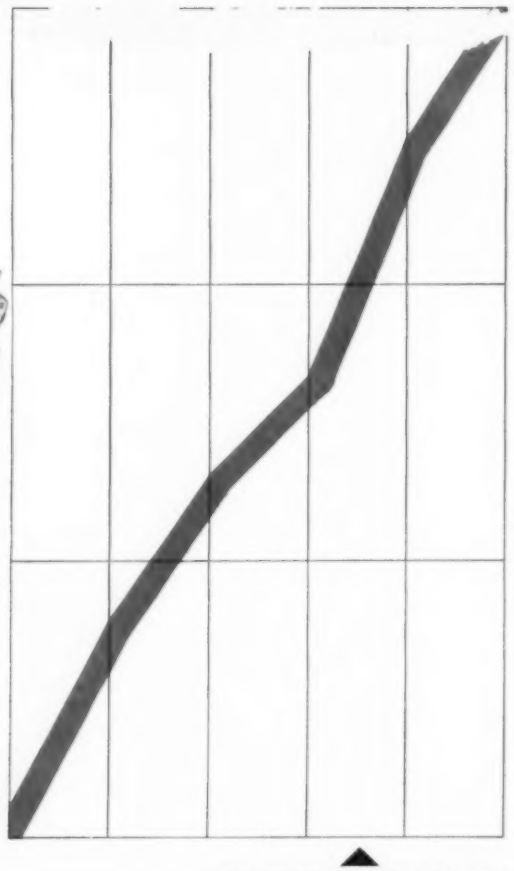
P. 2—Polyethylene Coated Board—THE MARKET IS GROWING

P. 3—Predicting End Properties of Blended Resins

P. 4—How to Increase Your Market

Polyethylene Coated Board—

the market is growing



DETAILS ON BACK

Polyethylene extrusion-coated board is replacing conventional coated board in more and more applications. In packaging food and dairy products, furniture, chemicals, industrial parts, users are finding that only polyethylene offers all these advantages: EXCELLENT WATER VAPOR RESISTANCE • SUPERIOR GREASE RESISTANCE • HEAT SEALABILITY • GOOD ADHESION OF COATING • TOUGHNESS AND SCUFF RESISTANCE • WILL NOT SCRATCH OTHER SURFACES • PRINTABILITY • NO TASTE, NO ODOR, NO CONTAMINATION OF FOOD FROM COATING SUBSTANCE

In Polyethylene Coating, PETROTHENE® Resins Give You Top Results—

HERE'S WHY: PETROTHENE polyethylene resins are made at U.S.I.'s modern, integrated facilities at Tuscola, Ill., and have several important advantages over many other polyethylenes. PETROTHENE resins have good draw-down properties which enable you to coat at appreciably faster production rates. They give you good adhesion, with minimum hot melt oxidation. And PETROTHENE coatings have no taste or odor—an important consideration in many packaging operations. For all polyethylene extrusion coating applications, take advantage of the properties of PETROTHENE polyethylene. It costs no more.

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To develop new markets and increase polyethylene coated board sales in present markets, U.S.I. is sponsoring a series of ads such as the one at left. These ads tell your customers about the market advantages of polyethylene-coated board. The series will run regularly in leading trade publications. For reprint copies of these ads as they appear, write:

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16 point board with a 14.4 lb. (1 mil) coating of PETROTHENE® 205 polyethylene resin. PETROTHENE coatings can be drawn down as low as 1/10 mil thickness.

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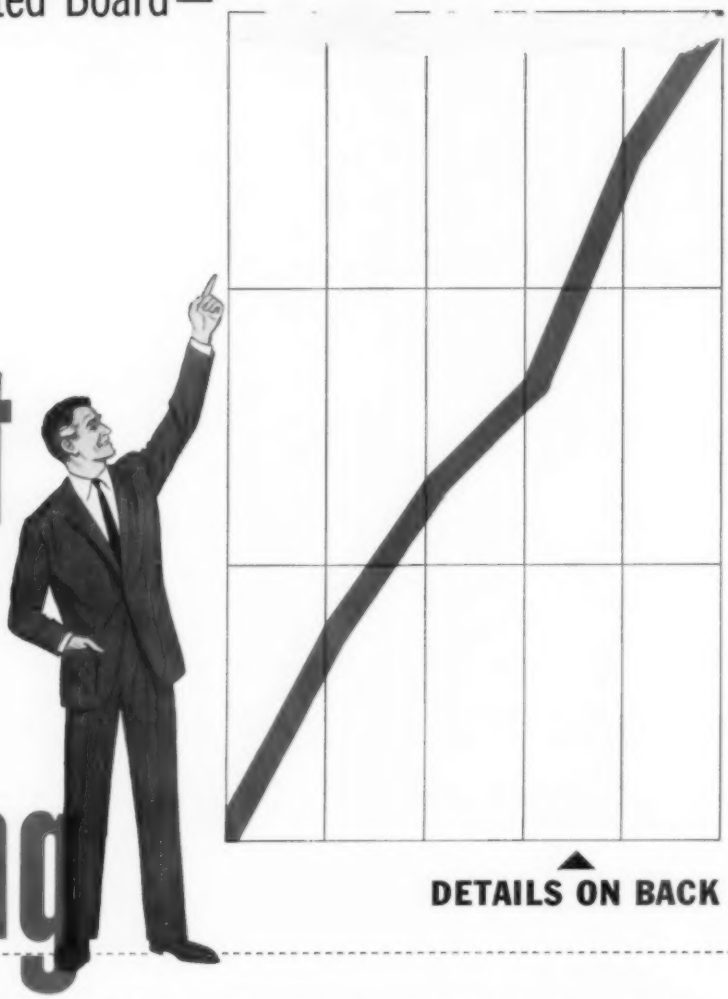
Polyethylene Coated Board—

the market is growing



DETAILS ON BACK

Polyethylene extrusion-coated board is replacing conventional coated board in more and more applications. In packaging food and dairy products, furniture, chemicals, industrial parts, users are finding that only polyethylene offers all these advantages: EXCELLENT WATER VAPOR RESISTANCE • SUPERIOR GREASE RESISTANCE • HEAT SEALABILITY • GOOD ADHESION OF COATING • TOUGHNESS AND SCUFF RESISTANCE • WILL NOT SCRATCH OTHER SURFACES • PRINTABILITY • NO TASTE, NO ODOR, NO CONTAMINATION OF FOOD FROM COATING SUBSTANCE

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Vol. III No. 2

POLYETHYLENE PROCESSING TIPS

PREDICTING END PROPERTIES OF BLENDED RESINS

A polyethylene processor may attempt blending of resins either for economic reasons or to attain a specific set of properties.

He may be successful, but blending, in general, is not considered good practice because it is difficult to obtain a homogeneous blend and the end results are difficult to predict – especially if the resins are from different manufacturers.

However, if you find it necessary to blend, it is possible to predict certain end properties with reasonable accuracy.

Melt index and density are predictable

Assuming that your polyethylenes are closely enough related, it is possible to blend for specific melt indexes and densities and therefore to obtain the desired properties that are functions of either of these.

The chart and the formula given here will enable you to predict either melt index or density. If you are blending for melt index, the logarithmic average will give the correct figure. Simply follow the directions in the caption under Figure 1. If you are blending for density, the arithmetic average will be correct. Simply use the formula described in the example given with Figure 2.

Recommended Precautions

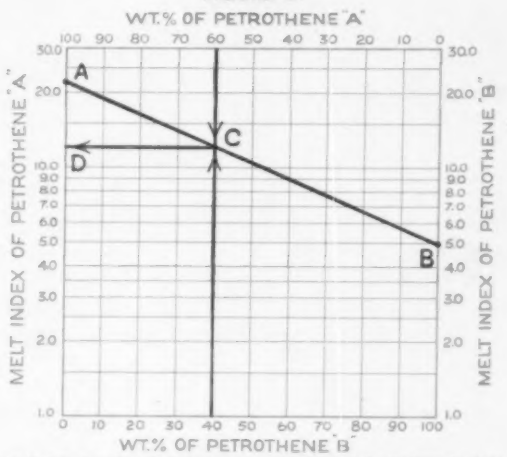
It is recommended that you limit yourself to injection molding when working with resin blends. If you are using a rotary drum for mixing, allow a tumble time of at least 20 minutes.

Shots should be relatively large, limited generally to about eight ounces in single cavity molds and twelve ounces in multiple cavity molds. Restrictive gatings, back pressure plates or similar devices, however, promote homogeneous mixing and sometimes smaller items can be effectively molded when these devices are used.

U.S.I. offers technical assistance

An answer to your individual need may well be found in obtaining directly from a manufacturer a polyethylene resin with the properties you want. And remember that U.S.I.'s Technical Service Engineers are always ready to work with you in finding the solutions to specific resin property problems.

FIGURE 1:



To Determine the Melt Index of a Blend of Polyethylene Resins having Different Melt Indexes –

1. Assume you are blending 90 pounds (60%) of U.S.I. PETROTHENE® 202 polyethylene resin with 60 pounds (40%) of PETROTHENE 201.
2. Petrothene 202 has a melt index of 22.0. On the left hand scale, therefore, fix a point at 22 (indicated by "A").
3. Petrothene 201 has a melt index of 5.0. On the right hand scale fix a point at 5 (indicated by "B").
4. Draw a line connecting 22 and 5.
5. Since you are using 40 percent of resin B(201), fix a point at 40 on the bottom and draw a vertical line.
6. From the point where these two lines intersect ("C"), draw a horizontal line so that it intersects the left hand scale ("D").
7. At "D" you now can read the melt index of your proposed blend.

This technique can be used to calculate the melt index of two polyethylene resins from the same manufacturer. If you do this type of blending frequently, you can set up these scales on any semilogarithmic graph paper. Your U.S.I. Technical Service Engineer will show you how.

FIGURE 2:

(% A) × Density of A + (% B) × Density of B = Density of blend

To Determine the Density of a Blend of Polyethylene Resins Having Different Densities –

1. Consider that you are mixing 105 pounds (70%) of U.S.I. PETROTHENE 206 (density 0.924) with 45 pounds (30%) of PETROTHENE 201 (density 0.916). Call resin 206 "A", and resin "201" "B".
2. Substituting these quantities and densities for the symbols in the formula above, you get the following numerical equation –

$0.70 \times 0.924 + 0.30 \times 0.916 = 0.9216$

3. The density of your blend therefore is 0.9216.

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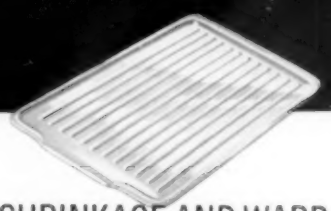
HOW TO INCREASE YOUR MARKET FOR MOLDED POLYETHYLENE PRODUCTS...

We all know what a good plastic material we've got in polyethylene. It's durable, attractive and economical. But remember—the sales appeal of molded polyethylene products is based on SERVICEABILITY. In the long run, the size and growth of your molded polyethylene market depend on how well you build quality into your products. It's not an easy job. Here are a few typical problems that molders encounter frequently, and some of the suggestions that U.S.I. technical service people have come up with:



LOW TEMPERATURE FLEXIBILITY

Understandably, there's little market future for polyethylene garbage cans that shatter on a cold winter's morning. The secret of getting good low temperature flexibility lies in proper resin choice. Look for resins with low density. As far as melt index is concerned, the lower the better for low temperature flexibility—providing the resin can be molded without going to pressures that will cause locked-in stresses. Avoid unrelieved stresses caused by poor design or molding techniques. And use-test your finished product—theoretical resin brittleness values may not mean much under practical conditions.

Recommended PETROTHENE® resins: 202, 203, 206, 207.

STRESS CRACK RESISTANCE

Why will a polyethylene carboy safely carry sulfuric or hydrofluoric acid, while a housewife's dishpan may split from the chemical effects of ordinary household detergent? The answer again involves stress and choice of resin. Specifically, resins of higher molecular weight or lower melt index, and polyethylenes of narrow molecular weight distribution, such as Petrothene resins, have less tendency to crack under environmental stress. Residual strains left after molding will also have a marked effect on stress crack resistance.

Recommended PETROTHENE® resins: (for housewares): 200, 203, 205, 207.

SHRINKAGE AND WARP RESISTANCE

Molded products are moving into new markets where dimensional accuracy and stability are essential. Warpage in flat items, such as drainboards and large covers, is chiefly affected by molding conditions. However, resins of lower density and lower average molecular weight will have slightly less tendency to warp. Shrinkage, too, is a result of molding conditions, especially temperatures, but here again resins of lower density are less subject to shrinkage.

Recommended PETROTHENE® resins: 201, 202, 203.

For advice on specific molding problems and resin selection, contact U.S.I. Technical Service.

HERE'S HOW U.S.I. HELPS YOU TELL YOUR CUSTOMERS ABOUT THE MARKET ADVANTAGES OF QUALITY IN POLYETHYLENE PRODUCTS

In a series of ads like the one at left and in an illustrated booklet, "The Goose that Laid the Golden Egg," U.S.I. is presenting to buyers of housewares and other molded polyethylene products the reasons why quality is their best market booster. The ads and booklet emphasize the importance of well designed, well molded, serviceable products in maintaining consumer confidence in polyethylene. The program is designed to help tell your customers the advantages of dealing with you, the quality molder. Reprints of these ads and copies of the booklet for you to send to your customers may be obtained by writing to U.S.I.

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Effect of Processing Conditions Upon Specific Gravity of High Density Polyethylene

J. P. Fogerty and E. Poindexter

W. R. Grace & Company
Clifton, New Jersey

The advent of heterogeneous catalysis for the production of polyolefin resins introduced into the plastics field a new type of polymer with different properties. One of the most widely publicized properties of the new types of polyethylene developed in the past few years is their higher density as compared with high pressure polyethylene. It is generally understood that the basic reason for the achievement of higher density is the considerable reduction in branching and the higher degree of crystallinity. It was apparent from the time initial test results were obtained on these new polyolefins that these differences in branching and crystallinity resulted in different physical properties.

As is generally the case with a new polymer, differences in flow existed which precipitated the need for variations in processing conditions and in some cases required the design of new equipment and changes in existing equipment. Realizing that these differences may be affected by processing conditions, a study was undertaken to determine the effect of variations in molding conditions upon density. It was felt that information on the possible variations in density would shed more light on an understanding of the variations in physical properties and, more important, an understanding of the flow properties of high density polyethylene. A thorough study of the property of density was chosen for this work as 1) density has a definite effect on physical properties, 2) the density of some plastic materials is affected by processing conditions, 3) crystallinity is affected by variations in processing.

Work has been performed in the past on the compressibility of plastic materials and also on high density polyethylene but it was decided to investigate this property from a practical view point by the use of an injection molding machine. By performing the work on production equipment, the actual pressures at which short shots and flashing normally occur could be bracketed and processing temperatures and conditions would also be duplicated. The work would then be of value to the molder and would result in a better understanding on the behavior of this material in the molding operation.

Procedures

For the purpose of this investigation, high density polyethylene was molded in a four-cavity mold, ⅛" gate. The cavities were ¼" x ½" x 5" impact bars which were end gated. End gating was chosen for the purpose of this study as the pressure of the ram would be transmitted in a straight line and the maximum degree of packing would then be achieved. This point was very important as a purpose of the study was to determine if a packing effect existed. The following conditions were used in the molding study:

Molding Conditions

Hold Time	Cylinder Temperature	Material Temperature	Mold Temperature	Pressure*
20 sec.	350°F	350°F	32°	2,000 psi
30 sec.	400	400	100	to
40 sec.	450	445	150	16,000 psi
	500	495		
	550	545		
	600	590		

*See Text

The variations in the above conditions resulted in 255 different samples. The figures listed as hold times represent the time the ram was in the forward position while a total cycle of 60 seconds was used in all cases. The pressure ranges varied from 2,000 psi to 16,000 psi for the whole study but, for the individual sets of conditions, the lowest pressure at which the mold cavities were completely filled and the maximum pressure at which flashing occurred were used. In practically all cases this range was far less than 14,000 psi.

Before performing the actual density study, bars from the four cavities were evaluated for possible differences in density and, even though no significant differences were noted, one cavity was chosen for all of the studies. For the actual determination of density, the im-

This paper is a revised and extended version of the paper presented at the Fourteenth SPE Technical Conference.

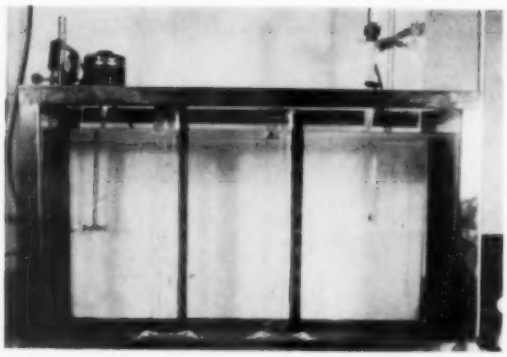

Figure 1 (above). Closeup View of Apparatus Used in the Density Gradient Method.

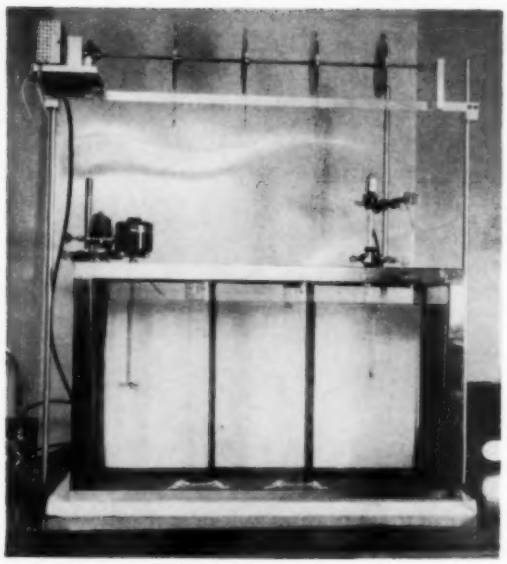

Figure 2 (right). Overall View of Complete Setup Used for the Determination of Densities.

pact bar was divided into three sections by removing ½" off each end of the bar and then cutting the bar into two pieces. Samples were then taken ½ inch, 2-½ inches and 4-½ inches from the gate end for density determination.

Figure 1 is a closeup picture of the density gradient method which was used for the determination of densities. This method was chosen due to the accuracy achieved, which is in the fourth place. It very simply consists of a column which is carefully filled with liquid mixtures of various densities, composed of alcohol and water, so that the density varies in a straight line function from the bottom to the top. Glass floats, on which the density has been determined to the fourth figure, are placed in the column and their position versus density plotted on graph paper. Small cuts of plastic from the impact bars are placed in the column and the density is read when the sample has settled to its equilibrium position. More details are described in A.S.T.M. Tentative Test Procedures.

Figure 2 is an overall picture of the complete setup showing the wheels which are used to raise the baskets to the top of the column when the columns contain too many samples. As a point of information, the basket is raised at a very slow rate taking one hour to travel from the bottom to the top of the column.

Results

The total cycle time was maintained at 60 seconds and the rate of forward travel of the ram was held constant but the hold time for the plunger in the forward position was varied from 20 seconds to 30 seconds and to 40 seconds.

Hold Times

No significant difference could be determined on the property of density at the various pressure and temperature levels even though the hold time was varied. This lack of change in density is significant as it means that regardless of the mold and cylinder temperatures and variations in pressure, the rate of cooling is so rapid as the molten polymer enters the mold that the length of time of application of pressure has very little effect on density.

This should not be construed as a recommendation for short hold times as other factors are influenced by hold time and must be considered in the manufacturing of an acceptable piece.

Cylinder Temperature

The cylinder temperatures were deliberately varied over a very wide range to determine if temperature had any significant effect upon the property of density. It was determined that at various temperature levels there was a slight increase in specific gravity as the temperature was raised. This difference was especially apparent in the range of low pressures and low temperatures but was not as noticeable in higher ranges.

Pressure

The next variable that was investigated thoroughly was the effect of pressure upon density. As a "packing" effect can be achieved with many plastic materials, this variable was especially important in determining if high density polyethylene was susceptible to this phenomenon.

On Figure 3 is a graph showing the effects of ram pressure upon density at a mold temperature of 100°F. It can be noted that at low material temperatures pressure has a definite effect upon density. As the cylinder temperature is increased to 400°F the density of the molded item at low pressures is slightly higher than at 350°F but the final density at high pressures is still the same as at 350°F. As the cylinder temperature is increased still further to 500°F and higher it was determined that density is not affected by pressure. This information indicates that a slight compressibility does occur in the mold at lower processing temperatures but, as the temperature increases, the resistance of the polymer to pressure is decreased and specific gravity remains constant. It has been shown in previous studies that within intermediate temperature ranges specific gravity is affected but, at high temperatures and also at low temperatures in the vicinity of the crystalline melting point, specific gravity is not affected. Indications are that this condition is occurring in the mold at the lower temperature levels.

Mold Temperature

The degree of crystallinity in high density polyethylene can be as high as 90% or it can be lower depending upon the method and conditions of fabrication. This can be shown very easily by compression molding samples and using different methods of quenching and annealing.

For this part of the study mold temperatures were deliberately varied over a very wide range to determine if they had an effect upon density. On Figure 4 is shown the effect that injection molding at various mold temperatures has upon density. Three curves are shown for material temperatures of 400°F, 500°F and 600°F. The position of the three curves is approximately the same with a slight increase in density as cylinder temperature is increased.

However, a definite increase in density is realized as the temperature of the mold is increased. The rate of change in temperature of the material is dependent upon the mold temperature with lower temperatures resulting in a more rapid rate of change while higher mold temperatures produce a slower rate of change. Even though the relationship between the degree of crystallinity and the rate of transfer from the molten state to the solid state has been explored previously, this shows that the factor of mold temperature influences specific gravity.

Impact Strength

As impact bars were used for this study, it was only natural that a few notched Izod impact strengths would be run to determine if molding conditions had any effect upon impact strength. This feature became increasingly important as work progressed to determine the relationship, if any, between impact strength, crystallinity and packing. Tests were run using a Bell Laboratory Impact Tester.

It was determined that the variables of hold time, pressure and mold temperature had no significant effect on impact strength but cylinder temperature did have an effect. Figure 5 lists the effect of cylinder temperature upon impact and it will be noted that maximum impact strength was achieved at approximately 450°F, while in the neighborhood of 600°F, impact strength was reduced considerably; which was probably due to degradation. An interesting feature that was noted on this property was the variation in strength between the gate end and the far end. Each five-inch impact bar was cut in half and two readings were obtained, one at the gate end and one at the far end and these results were averaged separately and together. The average results for the whole bar showed that only cylinder temperature had a definite effect upon impact strength and, as previously mentioned, the other variables of pressure, mold temperature and hold time were not significant factors. It was noted, however, that mold temperature did have an effect upon the amount of variation in impact strength between the gate end and far end.

Variations in Impact Strength Across The Bar

Mold Temperature	% Variation
32°F	48
100	29
150	15

At a mold temperature of 32°F the impact strength at the gate end averaged 48% higher than the impact values at the far end. At a mold temperature of 100°F this difference in strength was reduced to 29% while at 150°F it was reduced still further to 15%. This difference is especially interesting as no significant differences in density could be determined across the bar. It was noted that the density showed a slight decrease across the bar traveling from the gate end to the far end but no great differences were noted. It is known that as polyethylene flows across a mold, turbulence occurs at the flow front

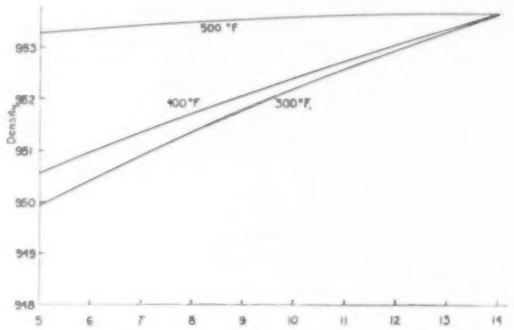

Figure 3. The Effects of Ram Pressure on Specific Gravity.

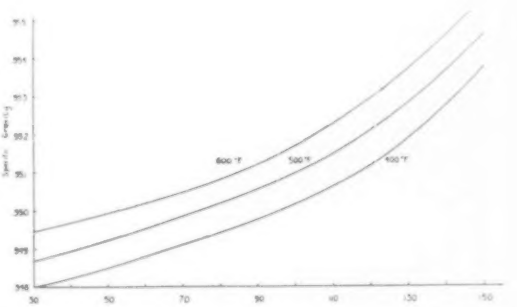

Figure 4. The Effect of Various Mold Temperatures Upon Density.

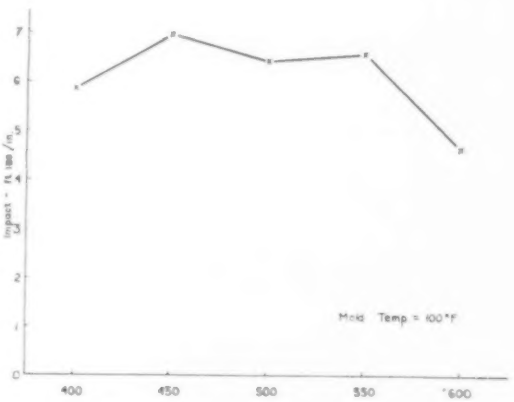

Figure 5. The Effect of Cylinder Temperature Upon Impact.

due to a cooling of material and an increase in viscosity at this point. As the flow front progresses across the mold, turbulence increases due to a further increase in viscosity. Due to the presence of turbulence in the flow front, residual stresses and strains are induced and thereby result in a weaker section. A lowering of mold temperature could, in effect, cause a more rapid decrease in the temperature of the polymer, thereby resulting in more turbulence and causing a larger difference in strength between the gate end and far end.

Annealing

The actual density of the virgin resin is .960. However, all of the densities determined on the molded items ranged from .948 to .955. Therefore, the molded items were annealed and quenched at various conditions to determine the effect of re-heating upon specific gravity. From a more practical angle, it is sometimes necessary to heat molded items at elevated temperatures to relieve thermal and mechanical stresses induced in the molding operation. In most commercial applications, it is likely that annealing temperatures below that of boiling water will be used to insure against warpage. For the purpose of this investigation, however, annealing temperatures of 149°F, 212°F and 266°F were used.

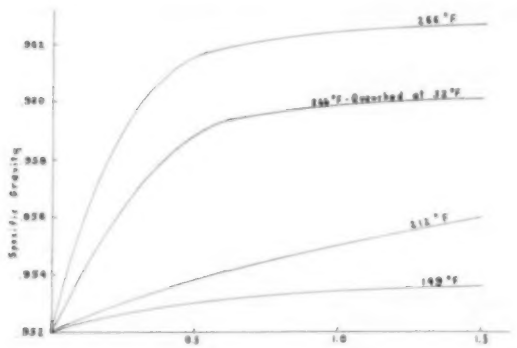

Figure 6. The Densities of Injection Molded Samples Plotted Against Time.

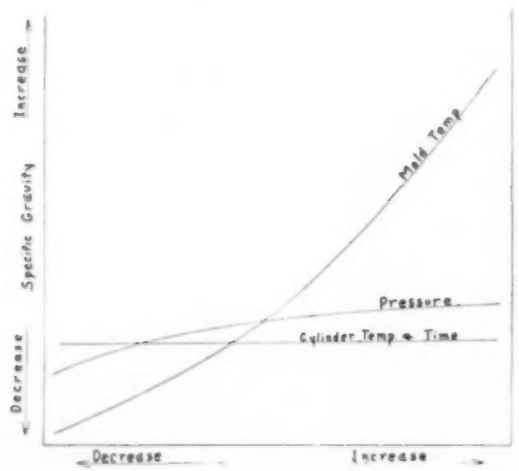

Figure 7. The General Relationship of Molding Conditions Upon Specific Gravity.

In Figure 6, the densities of injection molded samples are plotted against time for the temperatures mentioned. The curves show that as temperature increases, the density also increases with the major change occurring in thirty minutes or less.

In addition samples were annealed at 266°F for the time intervals indicated and then quenched in ice water. As the curve shows, this operation resulted in specific gravities lower than obtained by cooling at room temperature but were still higher than those obtained by annealing at lower temperatures. This indicates that below the crystalline melting point, the temperature at which annealing is performed is the predominant factor on the specific gravity of the final item.

Conclusions

On Figure 7 is shown a general graph of the results obtained relating the effects of molding conditions upon specific gravity. It is shown that hold time and cylinder temperature have little effect upon specific gravity. The slope of the curve for pressure shows that high density polyethylene is compressible but, it must be remembered that the condition of compressibility occurs within a temperature range and, as higher temperatures are achieved, the compressibility effect is lost and specific gravity is not affected. The final curve shows that mold temperature has a definite effect upon specific gravity with higher mold temperatures promoting the growth of crystals and thereby increasing gravity. This fact is further explained through the data on annealing when higher annealing temperatures and times resulted in higher specific gravities.

These data show that mold temperature control is of the utmost importance for the production of molded items that have minimum strains. For the equalization of cooling rate of material throughout the part, a temperature gradient is necessary. However, the degree of gradient will be dependent upon the size and thickness of the part. For a small and thick sectioned item, such as was used in this work, a gradient is not too necessary, but as the size of the item increases and the wall thickness decreases, the careful adjustment of gradient is very important. The use of a temperature gradient is an attempt to equalize the rate of cooling throughout the mold so that equal crystallization is obtained. This condition can also be achieved through faster removal of heat in the gate area by the insertion of highly conductive metals.

Mold temperature is also important for the preparation of items with the best possible impact properties. It has been shown that higher mold temperatures result in a better equalization of impact strength throughout the molded item. ★ ★

References

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2. Westover, R. F., and Maxwell, Bryce, "Flow Behavior and Turbulence in Polyethylene," S.P.E. Technical Papers from National Meeting in St. Louis, page 453 (1957).

3. Maxwell, B. and Matsuoka, S., "Bulk Compressibility of Polymers at Fabricating Temperatures," S.P.E. Journal, 13, 2; 27 (Feb. 1957).

AUTOMATIC INJECTION MOLDING

Quentin M. White

F. J. Stokes Corporation
Philadelphia, Pennsylvania

The continuing search for truly automatic molding techniques by the injection molding industry has been given added impetus by rising direct labor and mold costs. Automatic injection molding also brings with it improved quality control possibilities. Its acceptance and proper utilization will allow molders to compete with other materials to a greater extent.

Automatic injection molding has had different meanings at different times and even today several degrees of automation exist.

Shortly after injection machines became power operated, controls were installed on some units to permit them to close, inject, and open with a mechanical stroking of the ejectors and close again on a continuous cycling basis. For some parts a complete shot including the sprues and runners was ejected from the machine and the machine closed again without any manual operations having taken place. It was found that even though flush ejector pins were used, many of the parts would stick to the surface of these flush pins and not fall by gravity from the machine. Die damage very often resulted and an operator was placed on the machine to protect the dies. This procedure never gained wide acceptance throughout the injection molding industry.

The next step was the addition to these continuous cycling presses of a clearing arm. This particular device took many forms. The earliest and perhaps most generally used device was a mechanically operated arm which would drop through the die area after the mold had opened and would be retracted from the die area as the mold was closing. The timing and placement as well as the configuration of such an arm was sometimes very critical. In many cases the parts were so small that they could not be dislodged by such a clearing arm. In addition some parts were too delicate to be struck by such a clearing arm. Even though this provided a more positive way of discharging pieces from the die, full shots complete with sprues and runners were ejected and a secondary operation was necessary to accomplish the degating. In view of the labor still required to do this degating, as well as the problems of working with such a clearing arm, this technique was not generally accepted.

This paper was presented at the Fourteenth SPE Technical Conference.

Present Techniques

The next advance in automatic molding was the development of air ejection systems coupled with a low pressure closing device. The machines were designed and built to operate continuously. A short time delay was made at the full open point in every cycle. At this point, a directional air blast was given, ejecting the runners and parts with the aid of gravity from the machine. In addition to this ejection motion, the machines were equipped with a sensitive low pressure closing device. The dies were closed under extremely low pressure and should any part remain in the mold, the high pressure would not be permitted to enter into the hydraulic circuit and the press would open again and stop.

A further modification to this technique was made to eliminate the amount of labor required in degating. Self-degating dies were built for many jobs, and these dies have taken many forms. Among the most common is the use of tunnel or submarine gating. In this particular type of die, the runner is brought to within 3/64" of the edge of the part and then the gate is cut in under the surface. As the parts and runners are ejected, the bridge of metal over the submarine or tunnel gate shears the gate from the part. Tunnel gating, on parts where it is applicable, has met with varying degrees of success. One of the most common problems with tunnel gates is the plugging of the gate. Since the gate is not self-cleaning as a surface type gate would be, loss of production from the plugged cavity results.

The second problem is one of partial ejection. With two tunnel gates balanced on any part of the runner system, it is entirely possible that one gate will break clean from the tunnel before the other gate. When this happens, the commonly used flush knock-out pins will merely push the runner aside rather than eject it from the mold. If the runner is left in the machine, the press will close and interrupt the cycle through the low pressure close device. This type of gating was not practical on all parts and many dies have been built with

mechanical slides which actually shear the gates either on the opening of the press or the ejection of the parts from the mold.

Three-plate molds have been used in order to achieve automatic degating. These are normally more expensive to build and more subject to wear and maintenance than two-plate molds. Degating is done by the separation of the floating plate from the part. Knock-out pins must be built into the stationary half of the die to pull the runners from the floating plate and provide for their ejection from the stationary plate.

To avoid the problems of degating and ejecting the sprues and runners, as well as speeding up cycles and saving material, a great deal of work was put into runnerless or hot-runner molding. Runnerless or hot-runner molding was first adapted to container-like parts. Since these parts should be center gated and have projections which allow a hot nozzle section to be brought up close to a portion of the cavity without being brought into the proximity of other cavity formations requiring cooling, they are natural applications. These parts are ideal for stripper plates and air ejection. Since the objects are normally relatively large, or at least have relatively large projected surface areas, air can be used effectively.

In addition to the low-pressure-close, air-ejection, self-degating and runnerless molding die and press combinations there is another approach to automatic molding. The first method consists of using a basically conventional machine with adaptations for automatic molding and with dies built for automatic operation. The second concept is that of designing and building a machine for automatic molding which uses relatively simple and conventional dies. As far as automation is concerned, the basic differences between this machine and the conventional machine lie in the ejection system.

This system consists of separately actuated hydraulic top and bottom knock-outs, two combs, a tray and a scraper. As the mold opens, the runner is carried up with the moving half of the die. The parts remain on the stationary lower die. During this opening stroke, the parts are degated. The tray moves into position and the knock-out pins are advanced (Figure 1). The combs advance over the runners and under the parts (Figure 2). Retraction of the knock-out pins leaves the runner on the tray and the parts on the lower comb. They are then pushed into separate chutes by the scraper.

The current definition for automatic injection molding may then be, "a machine and mold combination which automatically molds and ejects finished parts with the only manual operations required being that of furnishing raw materials to the hopper and removing finished parts in bulk." It can be accomplished by two separate approaches. The first is to use a conventional machine with air ejection, self-degating or runnerless molds and low

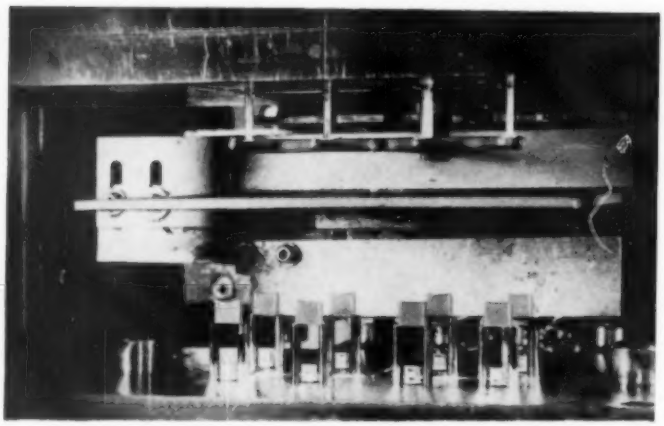

Figure 1. During the Opening Stroke the Parts Are Degated, the Tray Moves into Position, and the Knockout Pins Are Advanced.

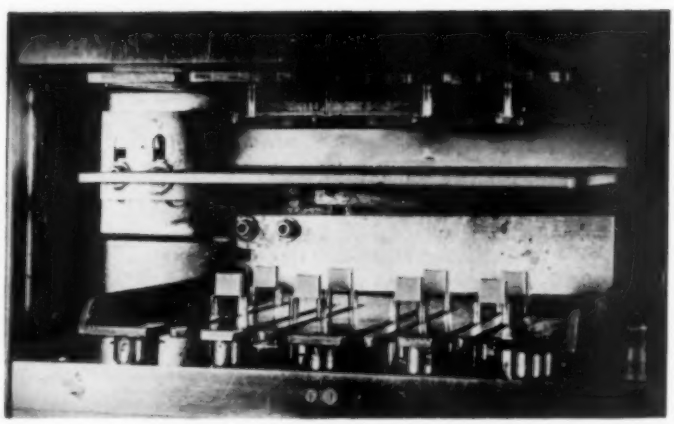

Figure 2. The Combs Advance Over the Runners and Under the Parts. Retraction of the Knock-out Pins Leaves the Runner on the Tray and the Parts on the Lower Comb.

pressure close protection. The second approach is to use a machine designed for automatic molding and conventional dies. There of course is considerable difference in the economics involved and the applications suitable for the two current methods of doing automatic injection molding.

Economic Considerations

There must be some reason that molders, machine builders and tool makers put money and effort into developing automatic injection molding equipment. Some of the reasons are very obvious, others are somewhat intangible items which each molder must evaluate for himself. Perhaps the most obvious and most discussed reason is one of the economics involved. The economic consideration can be broken down into two main portions, investment and production costs.

Capital Investment

The investment picture will vary considerably depending on which approach to automatic molding is selected. For instance, if a conventional machine and the additions for cycling this machine automatically and providing it with low pressure close protection is selected, very little additional machine investment is required. On the other hand, each mold designed to operate automatically in this machine must be built for automatic operation. The necessary self-degating features must be built into the die. Extreme care must be taken to assure parts staying on the moving half of the die without sticking so hard that flush type pins cannot eject them. Clearances between pins and the cavity must be maintained and if they become worn, must be replaced. If they are not, the small amount of flash molded around these pins will retain the pieces on the pin and keep them from being ejected. It may be also necessary to put a hydraulic or air operated sweep in the die to assure ejection of the parts. This work is not done without additional expenditure on the mold. The mold investment per cavity is increased. It is extremely difficult to estimate the amount this will be increased since it is dependent upon the part design. Some mold makers estimate from 1% to 10% as being the basic range. The plan affords the molder the use of a nearly conventional machine for automatic molding, but means an additional die investment for each job that is placed in the machine.

The second approach to automatic molding consists of buying an automatic molding machine and putting in it relatively conventional dies. In this particular case, the machine investment may be increased from 10% to 15% over the price of a conventional semi-automatic machine of the same size. However, this one additional investment is good for the life of the machine and can be amortized over its life. The molds need not contain any self-shearing or self-ejection features. The hydraulic knock-out system automatically degates, ejects and separates the parts from the sprues and runners on most two-plate or three-plate molds with knock-out pins or stripper plates. In most cases, no additional investment is required in the mold over a conventional mold. In some cases the mold will be cheaper due to the fact that a core in the die can be used as an ejector pin. This may eliminate the need for four or more ejector pins which would normally be used on a conventional type operation. This second approach has particular appeal to those companies, either custom or consumer, who cannot keep one die and one machine busy on a given part continuously. It can be seen that if the investment is made once in an automatic machine and the dies are kept relatively standard, that the total investment on a multiple mold per machine basis is considerably less than keeping the initial machine cost lower and making an additional investment on each of several dies. This is significant because of the fast amortization rate applied to dies. A recent survey indicates 73% of the molders amortize molds in six to twelve months.

Regardless of which approach is selected, once truly automatic operation is achieved a labor savings results. It is this continual quest for labor savings and cost reduction that has provided the basic economic incentive for automatic injection molding. In addition to this basic labor savings, there are savings in both set-up cost and running cost.

Production Costs

The ability to use smaller dies economically through labor savings has definite advantages in production costs. Tool size and cost can be tailored to suit the production requirements. However, the effect of automatic molding on set-up time varies considerably depending upon which approach to automatic molding has been selected. In the first case the set-up time of an automatic mold in a conventional machine will probably take longer than the set-up of a semi-automatic mold. This is due to the adjusting of the various motions within the die as well as the connecting of any wiper arm arrangements. If the second approach is taken a positive stripping action is provided within the unit. This means that the running conditions are not as critical as far as automatic operation is concerned. The comb plates are merely light metal parts which are screwed on to a holding bar. No line-up is involved since the carrying bar stays with the machine and is completely guided.

In addition to the elimination of a large portion of the direct labor, automatic operation also reduces the dollars expended in overhead. By reducing the number of people required to turn out a given production the facilities for these people can be reduced proportionately. Floor space for operators is eliminated and no additional floor space is required for degating fixtures and tools. In addition to this, automatic machinery is extremely flexible as far as loading is concerned. With conventional equipment a low demand period can only economically be compensated for by a reduction in the molding plant labor force. On the other hand an increase in production means rehiring and perhaps re-training operators to meet the increased load. With automatic equipment, presses may economically be shut down with very little inefficiency and can be re-started again without the addition of personnel.

There is another advantage in terms of quality. Small molds with a small number of cavities can be tooled and sampled quickly. Fewer variations will be made by the tool maker from cavity to cavity. Smaller molds mean less chance of temperature variations from cavity to cavity and also less chance of pressure variation from cavity to cavity. These two items, temperature and pressure, along with the third and perhaps most important factor of consistent repetitive cycles, mean less variation in the molding operation and closer tolerances in the molded pieces. The ability to degate and separate the sprues and runners and immediately discharge them into a grinder means less contamination of the material and increases the ability to use regrounds.

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Editor: Ernest P. Moslo

Russell M. Houghton is owner of Conap Company, Olean, New York, a research and development activity. He has built and operated a decorative laminating and molding facility, a vinyl sheeting converting plant, and until recently was President of Houghton Laboratories. During World War II, he was head of the Plastics Liaison Branch, Materials Laboratory, Wright Air Development Center, Dayton, Ohio. He is a member of several professional organizations.

Russell M. Houghton

Plastics Research and Development — *Fact or Fancy?*

Our business society has suddenly discovered the words research and development, along with motivation, creativity, brainstorming, and a host of other catch phrases. There are indications that some of our professional managers believe research people are sufficiently out of touch with horrid reality that they need to be instantaneously educated out of their bad habits. None has yet gone so far as to suggest scientists be encouraged to work without the incentive of worldly gain. Our research facilities are now supposed to turn out extraordinary devices and materials-or else. Of course any scientist knows that creative research is like (as George Seidel puts it) straightening teeth—it responds to gentle pressure rather than a blow in the mouth.

Dr. Reeves of Esso Engineering and Research states, with his usual clarity, that industrial research can best be defined as an organized effort on the part of a company to provide itself with the technology it needs for its present and future operations. This may sound like a rather simple definition but implicit in it is the relatively new point of view that the research organization is an integral part of over-all operations.

I am indebted to Dr. Hugo Junkers for my own research philosophy, which is summed up in the following words: "when an innovation is to be carried out in technical matters, the inventive idea represents but a small portion of the work leading to the final product. It will never suffice to carry out the conception with the means by chance at hand; e.g., the working it out in a model. It is necessary to submit the laws of aerodynamics and resistance, the structural shaping, materials, adaptation of work-shops, and even the requirements of the market to a systematic examination before the original idea may be pronounced a success. It is necessary to see how far such considerations can be made serviceable to the ideal end, or if the idea must be modified in order to become feasible. Such an examination must be a necessary point of departure if it is to respect the confines of economy, the approved results of science, and to apply her methods. But the work must remain subordinate to the uniform technical aim and therefore be under one control to allow for continuous adaptation, limitation, and mutual influencing of the individual departments busy with it. To repeat briefly, the realization of technical ideas must be the fruit of an institute of research (Forschungsanstalt) uniformly conducted, but covering many branches.

I know the correctness of the method and I am pleased to note that many of our major corporations are turning to the practice of it.

Industrial research is not something that can be left to a team of scientists isolated from other industrial functions. Its organization, planning, and control must be part of the planning and control of the whole industrial machine and management at all levels and in all departments has some part to play in it. "The scientists' first duty is to science." In the past it may have been, but it is no longer.

If we go back in history ten or twenty years, we find very few research organizations recognized as part of the industrial family. Today the research organization has very definite responsibilities, and, if it carries out these responsibilities, it must have equal status with sales, manufacturing and finance. It should be an operating division in its own right and is of interest to and interested in all phases of company operations.

There was a time not too many years ago when it was easy for a company with a diligent research organization

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SPEAKING OF EXTRUSION

Edited by R. D. Sackett
Technical Service Associate
Monsanto Chemical Company
Springfield, Massachusetts

Avoiding Wrinkles in Polyethylene Blown Tubing

Howard W. Woodham

Products Application Engineer
U.S. Industrial Chemicals Co.

IN THE EXTRUSION of blown tubing, most shops at one time or another have encountered wrinkling intermittently during film wind-up in producing all but the narrowest width and heaviest gauge films. This problem is both annoying and costly. Not only must the wrinkled roll be scraped, but reoccurence is almost certain unless the cause is corrected.

There are numerous factors surrounding the extrusion and winding process which are likely to be suspected of causing wrinkling. A careful and thorough examination of each of these should be made as soon as wrinkles appear.

"Frost Line" and Die Ring Adjustment as Factors

If the frost line on the ascending tube is too high it is difficult to control and may cause poor gauge control around the circumference of the tube, and uneven gauge in the film. This in turn could lead to an unbalanced pull in the roll nip or across the collapsing guides and result in wrinkling. (Melt temperature in the range of 280-325°F. is considered typical for most blown tubing operations.)

Improper adjustment of the die opening or orifice is the reason for wrinkles caused by irregularity in gauge. When this orifice is out of adjustment the melt extrudes from the die in an uneven pattern, permitting variations in gauge of the finished film. The heavier sided or thicker section of the tube as it leaves the die lips contains more heat and is not cooled to the softening point or frost line of the melt as quickly. The tube continues to expand in this area, grows thinner and ultimately shows as a higher localized part of the frost line. The frost line must always be as level as possible.

Correcting Bias

Bias is a frequent cause of wrinkling in blown polyethylene tubing. It might be described as a condition where distance around the one half of the tube circumference is greater or smaller than the distance around the other half. Often times this bias is not readily visible when observing the ascending tube. The bias causes excessive friction in the collapsing guides, or unbalanced pull at the nip which results in "ruffle-like" wrinkles across the center of the layflat width of the wound roll. Occasionally, these wrinkles may be transmitted to the edge of the tube before it is drawn through the roll nip. Uneven or thin gauge film at the edges of the ascending tube may show as "chevron" type wrinkles on the edges of the roll.

Again, uneven distribution of melt at the die lips, resulting in a surplus in one portion of the die, is the crux of this problem. It is often solved by adjusting the die orifice by moving the die ring slightly in one direction or another. Extreme care should be exercised in compensating film gauge by moving the die ring. Very slight rotation of the adjusting bolts will have a noticeable effect on film gauge.

Smaller corrections may be made by shifting the orifice of the air ring closer to that section of the tube circumference which is thicker. But remember, the thinnest area of the wound tube is usually the thickest film area as it leaves the die lips. The farther off-center this ring, the

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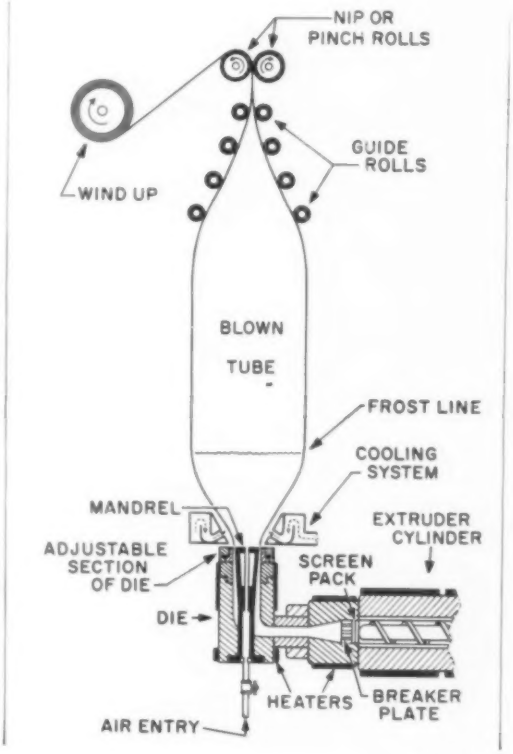
There are many possible causes of wrinkles in blown tubing. This diagram identifies some likely places in production equipment to which the problem may be traced.



Edited by **Louis Paggi**, *Consultant, E. I. du Pont de Nemours & Co., Inc.*

Causes of Flashing

Louis Paggi

THE PROBLEM OF FLASHING in the injection molding operation is a familiar one to all molders. In some cases it may be so difficult to control that tolerances on the amount of acceptable flashing must be specified.

Much can be done to control this problem, if due consideration is given to factors contributing to flashing.

Flashing Due to Part Design

Excluding the projected area of the shot and its effect on overcoming the clamp capacity of the machine, thin section parts will have a greater tendency to flash than parts composed of thick cross-sections. Among the reasons for this behavior are:

1. The required temperature of the material entering a mold for thin sections is usually at the upper level of the molding range. The higher heat content melt requires a relatively longer time to solidify. The high temperature results in a lower viscosity melt. Both of these conditions may allow the material to enter small crevices in the mold.
2. High material temperature reduces the pressure drop developed through the plastifying cylinder. This in turn increases the effective pressure developed within the cavity, thus increasing the load on the clamping device.
3. The resistance to filling, created by the thin section will result in a high back-pressure in the melt entering the cavity so that flashing can occur even in partially filled cavities.
4. Because of the relatively low volume requirement of a thin wall part, the rate of filling the cavity is high, therefore, the temperature of the material in contact with the cavity surface will not have dropped appreciably before full pressure is developed within the cavity.

A part designed with irregular surfaces such as corrugations, pits, grooves, etc. will require more pressure to fill than a part of equal thickness designed with a smooth surface. The part with the irregular surface will therefore have a greater tendency to flash.

Flashing Due to Mold Design

Many flashing problems can be eliminated or at least minimized, if proper precautions are taken in the design and construction so that it can be placed in operation without encountering some degree of difficulty. Since the exact molding conditions necessary for any given mold cannot be predicted, it may be necessary to subject the mold to one or more trial moldings followed by modifications before acceptable parts can be molded.

Among the design features to be considered are:

1. **Ridigity of the Mold**
   The injection molding machine and the design of the part often place limitations on just how rigid a mold may be made. Generous use of support pillars, support bars and heavy cavity plates may prevent local yielding at the parting line. In some cases, local yielding can be compensated for by mounting center supports with a slight interference fit. If this is done, firm seating of mold components will occur when the full clamping force is developed.
2. **Mounting of the Cavities**
   To insure positive seating of cavities at the parting line, it is standard practice to install cavities with their parting line slightly raised above the level of the parting line of the cavity plates. This is a good practice provided the cavities are not raised to a point where the runner system will flash with ease. Flashing of the runners should not be ignored, because when this occurs the projected area of the shot will be increased, thus decreasing the clamping force available to the cavities.

The back of the cavities should be firmly mounted against the cavity plate to eliminate the possibility of scale or dirt build-up between the cavity and backing plate. Non-uniform seating of the cavities can occur if the cavity pulls away from the plate with each opening of the mold.

3. **Venting**
   The importance of adequate venting as a control over flashing should not be overlooked. This is particularly true when molding thin sections because it is necessary to apply additional injection pressure to overcome the increased resistance to flow. If it becomes necessary to further increase the injection pressure to overcome the additional load of expelling highly compressed air from the cavity, flashing can result.
4. **Materials of Construction for Cavities**
   If the choice of material for the cavity is influenced only by the control over flashing, it is well to consider the relative heat conductivity properties of the metals available. For example, if the section is extremely thin and filling at normal pressure is expected to be borderline, we may wish to avoid rapid heat loss from the material by using a metal with low heat conductivity such as steel or nickel. If, on the other hand, the cavity can be easily filled but minimizing shrinkage by molding at high pressure is desired, it will become important to solidify a shell of material adjacent to the wall of the cavity before full pressure is developed. In this case, a metal with high heat conductivity, such as berrylium copper, should be considered.
5. **Coring of Mold Components for Temperature Control**
   If at all possible, the entire casting area of the mold should be at the same temperature. Floating or movable mold components not controlled in temperature may bind and wear due to

thermal expansion, unless installed with considerable clearance. Either condition may lead to flashing.

6. **Gating**
   The cross-sectional area of the gate should be large enough to permit rapid filling of the cavity when it becomes necessary.

Parts composed of thick and thin sections are less likely to flash if gated in the thinner section.

Flashing Due to Molding Conditions

Among the molding variables which contribute to flashing are:

1. **Drying**
   The melt viscosity of many molding compounds varies with the amount of plasticizer, solvent, monomer or water content as well as with the temperature of the melt. The effective pressure developed within the mold varies with the viscosity of the melt. Controlled drying of the molding powder should eliminate periodic readjustment of pressure or temperature to control flashing.

2. **Rate of Filling**
   Flashing in thin sections can often be minimized or eliminated by filling the mold rapidly. Rapid filling of the mold will permit complete filling while the material is at low viscosity. It can, therefore, be accomplished at a lower overall pressure. Slow rate of filling is usually preferred when molding heavy sections. This will permit a semi-solid shell to form around the molded item before full pressure is developed.

3. **Pressure**
   Several devices available to the molder can increase the flexibility of the pressure system of the machine. Among them are:
   (a) **Pressure Sensitive Nozzles**
   This device will by-pass the hydraulic pressure when the pressure of the material within the mold approaches the magnitude required for flashing.
   (b) **Mold Spreading Control**
   This device employs a sensitive limit switch which will by-pass the hydraulic pressure when the mold opens slightly at the parting line.
   (c) **Dual Pressure Pumps**
   This system can be used to increase or decrease the injection pressure by means of selection of oil from a given pump. Control is by means of timers. The mold may be filled at low pressure followed by application of considerably higher pressure after a pre-determined time. This time is established by the time required to form a solid skin around the molded item.
   (b) **Weigh Feeding**
   When the projected area of the shot is too large to be retained by the available clamping force, feeding of an accurately weighed charge followed by bottoming of the injection ram can prevent flashing. Here again rapid filling and good venting are factors which contribute to control.

4. **Temperature**
   The temperature of the material should not be higher than that required to fill at normal pressure. The setting of the temperature should not be established before the machine has been running for at least ½ hour, the reason being that the pressure transmitted to the mold will increase as the inventory of low viscosity melt increases in the plastifying cylinder. Equilibrium conditions of the melt will not have been established during the first few minutes of molding.★★

SPEaking . . .

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greater the chances of bias in the tubing. Generally the space around the mandrel or pin should be 0.015 to 0.025 inches, but this may have to be offset to compensate for the melt pressure loss around the mandrel.

The Nip Rolls—Likely Trouble Spot

Another logical place to continue the search for the cause of wrinkles is the nip rolls. Several problems can be traced to this portion of the equipment.

Slight eccentricities in alignment of these rolls might be the underlying cause of wrinkling. Worn bearings or a lateral drive thrust may affect their alignment if they are not rigidly supported. It is important that the rolls be absolutely parallel to insure uniformity of pressure. One recommendation is to fit the rear nip roll with small hydraulic cylinders, providing excessive pressure across the entire width of the rolls. The rubber surfaces of these rolls often subjected to contact by hot melt, will often quickly deteriorate, and they may need grinding and reconditioning to maintain proper resiliency.

Still another cause of wrinkling is associated with the nip rolls. If the collapsing guides or rollers are not in proper alignment with the nip, wrinkles will result. Most wind-ups built by the extruder manufacturers contain adjusting knobs for shifting the front-to-rear position of the collapsing guides or rollers. Also, the line of the roll nip must be positioned exactly above the die so that the tube will be pulled off exactly vertical during its ascent.

Other Causes of Wrinkling

If the ascending tube tends to wobble from side to side, this is probably a chief trouble spot. This motion might be due to melt surging from the extruder or to turbulent air currents in the room. A possible solution is to support the tube by horizontal stationary guide bars at two or three locations during its ascent.

Wrinkling is more prevalent at low gauge and high take-off rates. The thinner the gauge and the faster the take-off, the more important precise gauge control becomes. At film gauges below one mil very close control of the factors must be maintained to avoid wrinkles.

In general, the higher the density of the polyethylene used to manufacture blown tubing, the more susceptible it is to wrinkling. This is because the film has less flexibility—does not want to quickly conform to a flat shape from the blown tube. If the film is unusually cool as it reaches the nip rolls it may be more susceptible to wrinkling because it is too stiff. A slight increase in temperature here might reduce the stiffness and relieve wrinkling. But to avoid danger of blocking at higher film temperatures, other possible solutions should be examined first. If these fail and temperature must be increased, it can be accomplished in a number of ways —by carefully raising the melt temperature, increasing the screw speed (and nip roll speed) or slightly lowering the height of the nip rolls.

As can be seen in the foregoing paragraphs, wrinkling in blown tubing is a problem with numerous possible causes. There are undoubtedly some we haven't covered here, but these are some of the more commonly occurring ones and provide a good check-list for tracing the difficulty to its source. ★ ★

Contributions to the features Molding Cycles and SPEaking of Extrusion will be welcomed by the editors of these features. Comment on published material, additional information on the subject of a column, or criticism will be equally well received and considered for publication. Complete articles may be submitted, and suggestions for topics to be covered are solicited.

Your interest will be helpful and much appreciated.

The Editors

Service Report on

Glass-Reinforced Plastics Tanks

Ward B. Sanford

Minnesota Mining and Manufacturing Company
Ridgefield, New Jersey

THIS REPORT is the fourth in a series of reports giving service experience of glass-reinforced plastic tanks.[1,2,3]

Glass-Polyester Tank

Previous reports showed the circumferential measurements of a glass mat reinforced polyester 250-barrel oil field storage tank, both empty and full, during three winters and summers. As a comparison of empty and full measurements during the second and third summers showed little difference, the operator discontinued measurements on this tank.

In August of 1956, the tank suffered a tension failure at one of the staves. The failure was so extensive that it was necessary to junk the tank inasmuch as it could not be repaired. This tank had been in service since October 1952 or a total of 46 months.

Glass-Epoxy Tanks

Figures 1, 2 and 3 show the circumferential measurement of a glass-epoxy 250-barrel oil field stock tank and a 500-barrel wash tank. A comparison of empty and full measurements during the second and third summers for the 250-barrel tank shows only a slight change. In view of these developments the operator believes that very little creep will continue. It may be noted here that the average circumferential increase from empty to full tank condition for the glass-epoxy tank is less than one-half that of the glass-polyester tank.

The strapping of the 500-barrel tank is presented here for the first time. The 500-barrel tank is similar to the 250-barrel tank with the following exceptions: (1) the tank is 16 feet high instead of eight feet high, and (2) the tank has an aluminum deck. The average increase in circumference between the first and second summer for the 500-barrel tank was 0.020 as compared to 0.006 feet for the 250-barrel tank.

The operator reports that he has eight glass-epoxy tanks in service and is well satisfied with this type of tank. The only deficiencies yet observed in any of them are (1) a few minor seam leaks such as are present on any bolted tank, and (2) occasional small seepages through some of the staves. These seepages do not yet appear to be of any real consequence.

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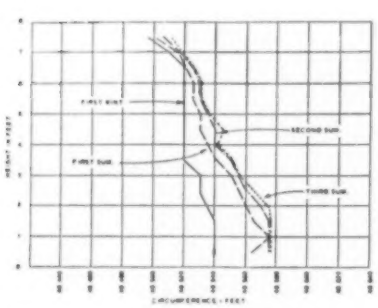

Figure 1—Circumferential measurements on a full 250-barrel glass-epoxy tank.

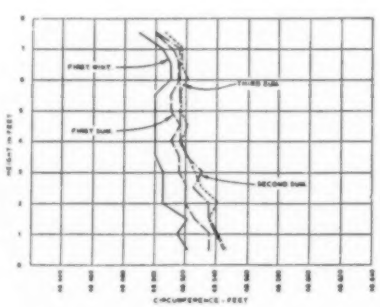

Figure 2—Circumferential measurements on an empty 250-barrel glass-epoxy tank.

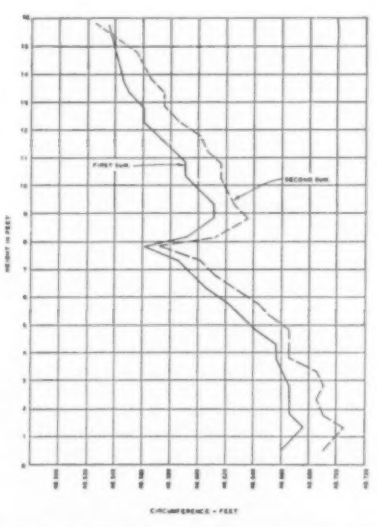

Figure 3—Circumferential measurements on a full 500-barrel glass-epoxy tank.

Film of **TENITE POLYETHYLENE** is taking over many packaging jobs

Garment bags are a good example of the growing use of polyethylene film. When laundries or dry cleaners return garments in bags of polyethylene, your clothes are getting the best possible care.

Film extruded of Tenite Polyethylene is a tough material that doesn't tear, puncture or "run" easily. And being waterproof, polyethylene film means extra protection for cleaned garments—especially if they must be delivered or carried home in the rain. The transparency of polyethylene bags also helps you and the cleaner identify contents quickly.

Long service life is another advantage when you have to store out-of-season clothes after cleaning. Polyethylene bags find many other re-use jobs, too, either as handy bags for a score of household chores or when cut open as film for wrapping.

Toughness, waterproofness and transparency are only three reasons why film remains the biggest single market for polyethylene. Its heat-sealability makes it the logical choice for use in high-speed automatic packaging machines. Polyethylene is also the lightest of all plastics widely used for film—a pound of this film goes further than a pound of other plastic film of equal thickness. And because polyethylene resists chemical and solvent attack so well, this plastic is used to package merchandise ranging from pickles to battery acids.

If you need a film for packaging, investigate polyethylene. We'll be glad to help you explore the usefulness and usability of film extruded from Tenite Polyethylene.

For more information on this versatile plastic, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

TENITE
POLYETHYLENE
an Eastman plastic

Polyethylene film extruded by
Chippewa Plastics, Inc.,
Chippewa Falls, Wisconsin

METHYL ETHYL KETONE

Trays, tables, desks, lamps and many other pieces of fine furniture are being finished with acrylic lacquer to assure a durable and beautiful surface coating. One of the important solvents in this new lacquer is Methyl Ethyl Ketone, supplied by the Enjay Company.

Methyl Ethyl Ketone also plays an important part in automotive finishes. Car bodies finished with acrylic lacquers are almost chip-proof. For *your* solvent needs—specify Enjay M.E.K.*

Don't miss our booth at the PACIFIC CHEMICAL EXPOSITION.

**Methyl Ethyl Ketone*

ENJAY COMPANY, INC., 15 West 51st Street, New York 19, N. Y.

Other Offices: Akron • Boston • Charlotte • Chicago • Detroit • Los Angeles • New Orleans • Tulsa

ENJAY

Pioneer in Petrochemicals

FOR COMPLETE INFORMATION on specifications and performance characteristics of Methyl Ethyl Ketone, contact the nearest Enjay office. Shipments will be made from conveniently located distribution points in tank car, truck, or 55 gal. drum quantities.

Action— By Your National Organization

"The objects of the Society shall be to promote in all lawful ways the Arts, Sciences, and Engineering Practices and Standards connected with the utilization of plastics."

An Open Letter to SPE Members

We look for this to be a year of great accomplishment for the Society of Plastics Engineers. Further growth will in large measure be attributable to the continued participation of the members in the Society's activities.

Listed herewith are the broad, overall goals for 1958. Dates for accomplishment coincide with regular meetings of the National Council, governing body of SPE, which are scheduled for the months of April, June and October. It is also probable that a special Council meeting — a Constitutional Convention — will be required during the year to consolidate our gains.

These are ambitious goals! I know that our membership shares with its National Officers the aspiration that these goals be reached. To do so will require the active work of a large segment of members. I am certain each of you realize that our 1958 goals are not something that National Council and staff can accomplish alone — we must all work together. I know that we can count on your complete cooperation.

Respectfully submitted,

Ken Gossett

R. K. Gossett
National President

SPE GOALS FOR 1958

I. Special Projects of National Executive Committee and Staff

1. Publish National President's Annual Report of Operations for 1958 calendar year to be mailed to each member of the Society in January, 1959.

2. Develop Executive Secretary's Newsletter to be mailed quarterly to each member of a geographical Section Board of Directors summarizing decisions of National Council, staff suggestions, etc. — start May 1, 1958.

3. Visit to each Section at least once during 1958 by a member of the National Executive Committee and/or the Executive Secretary.

3. Draft basic plan for the reorganization of the management of the Society for approval of National Council—October 1958.

II. Administrative Operating Committees

1. Membership Committee:

a. Prepare membership brochure describing the privileges of membership in the Society — April 1958.

b. Membership Survey Questionnaire Summary— October 1958.

c. Study of Delinquent Members and Resignations — Report June 1958.

d. Increase of 1200 new members in good standing bringing total membership to 7,500 — January 1959.

e. Study methods for emphasizing desirability for joining SPE to prospective members in end-user industries — April 1958.

2. New Section Development Committee

a. Develop interest in six (6) new geographical areas for presentation of charter petitions to National Council by January 1959.

b. Prepare survey of potential new section growth for three year period 1959-1962 Report — October 1958.

3. Finance and Audit Committee:

a. Develop recommendation for standardized Section Accounting Procedure — Report June 1958.

b. Submit 1958-59 National Fiscal Year Budget for approval of National Council — April 1958.

c. Recommendation for deposit of surplus funds to Research Reserve and Contingency Reserve — April 1958.

d. Analysis 1957-58 Fiscal Year Budget-vs-Expense — Report October 1958.

4. Credentials Committee:

a. Recommendation for upgrading requirements for membership in various grades — June 1958.

b. Study move to review of all applications for membership only by National Credentials Committee — Report and Recommendation — June 1958.

(Continued on next page)

SPE Goals For 1958

(Continued from preceding page)

5. **Constitution and By-Laws Committee**
   a. Submit final draft new Constitution and By-Laws to National Council — June 1958.
   b. Constitutional convention for adoption of revised Constitution — October 1958.
6. **Publicity Committee**
   a. Study and recommendation of policy for National SPE Publicity to be implemented by staff after approval by National Council—June 1958.

III. Administrative Technical Committees

1. **Publications Committee:**
   SPE Journal
   a. Advertising increase in monthly page rate to 45 pages per month by January 1959.
   b. Analyze national coverage of SPE Journal potential advertisers — Recommendation April 1958.
   c. Complete study of printing costs for SPE Journal for report to National Council — April 1958.
   d. Increase of 1,000 non-member SPE Journal subscriptions. Total SPE Journal circulation January 1959 — target 9,500 copies per month.
   e. Devise at least four new SPE Journal technical features — for Council action June 1958.
   f. Approval policy for abridging SPE technical papers in SPE Journal — April 1958.
   g. Complete study of Journal format — Report April 1958.
   General
   a. Prepare contract for authors contributing to SPE "Engineering Volume Series" April 1958.
   b. Complete "Manual of SPE Publications Procedures" including recommendations for SPE editorial policy and procedure for revising and rating technical papers April 1958.
   c. Study format Volume V "ANTEC Preprint Book" for recommendation to National Council — June 1958.
2. **Meetings Committee Activities**
   a. Continue Work of Speakers Sub-Committee liaison with Professional Activities Group Chairmen to provide compilation of technical speakers list to be mailed to each geographical Section at least 3 times during 1958.
   b. Final report scheduling six (6) or more Regional Technical Conferences (RETEC) during 1958 — April 1958.
   c. Communicate with geographical sections to develop at least six (6) RETEC for 1959 — Report October 1958.
   d. Develop 2-day National Technical Conferences (NATEC) to be held 1959, 1961 and 1963 — submit plan for Council approval — October 1958.
   e. Solicit bids from Sections for sponsoring 20th ANTEC 1964 — June 1958. Study and recommendation of award — January 1959.
3. **Education Committee**
   a. Study feasibility of establishing short courses in Plastics Engineering in colleges and universities — Report June 1958.
   b. Establish sub-committee for "Student Membership" — activate on approval of this membership grade through Constitution revision — October 1958.
   c. Compilation and publication of list of courses offered in plastics and related subjects in colleges and universities — October 1958.
   d. Submit 5-year plan for "Engineering Volume Series" — 1959-1964 for National Council approval — January 1959.
   e. Submit 5-year plan for preparation of other books on plastics engineering to be sponsored by the Society — report to Council January 1959.
   f. Collect slides on subjects related to the plastics industry.
   g. Proposal for establishing refresher courses at extension or graduate schools of universities — October 1958.

IV. Technical Committees:

1. Complete and publish revision of book "Injection Molding" — October 1958.
2. Publish Engineering Series Volume II, "Principles of Thermoplastics Processing" — October 1958.
3. Appoint Editor and initiate preparation of manuscripts for Engineering Series Volume III "Principles of Thermosetting Processing" — for publication in 1959.

V. Professional Activity Groups

1. Develop liaison with 15th ANTEC Committee to provide P.A.G. assistance in solicitation and selection of scientific and technical papers to be presented at Annual Conference — January 1959.
2. Submit plan for publicizing activities of Technical Advisory Service for Council approval — April 1958.
3. Develop Coatings and Reinforced PAG — Council approval April 1958.
4. Establish and activate local Professional Activity Committees in each geographical section — progress report — October 1958.
5. Expand liaison with Publications Committee to provide greater SPE Journal coverage of PAG technical meetings and activities of Technical Advisory Committee — Report June 1958.

VI. Inter-Society Relations Committees

1. Develop procedures for regular activities reports to Council from SPE members serving as liaison representatives with other scientific and engineering societies.

VII. Ad Hoc Committees

1. "Committee to Study Section Election Procedures" — final report — April 1958.
2. "Committee to Study Communication between Geographical Sections and the Society" — final report — April 1958.
3. "Committee to Revise 'Section Procedures' Manual" — draft for Council approval October 1958. Publication — January 1959.
4. "Past National Presidents' Study Group" — report on desirability of SPE sponsored engineering displays in connection with ANTEC — report to Council — June 1958.
5. Establish Scientific-Engineering Liaison Committee — April 1958.

An Open Letter to Membership

April, 1958

Dear S.P.E. member:

This is your final invitation to write a technical paper for presentation at the 15th Annual Technical Conference of the Society of Plastics Engineers to be held in New York at the Hotel Commodore on January 27, 28, 29 and 30, 1959. However, in accordance with a National Council mandate, we are compelled to advise you that these papers must be devoid of "commercialism" and should contain only original and factual information of interest and importance to the plastics engineer. Please submit a 75 word brief *today*.

By this time you have received and we hope have returned both the general and detailed questionnaires on the 15th ANTEC program—providing you concomitantly with some insight into the conference format. The Speakers and Program Committees are now compiling and collating your ratings and suggestions for specific topics, so that the 15th ANTEC program may truly reflect the dominant interests of the S.P.E. membership. Simultaneously, the National Professional Activities Group Chairmen are soliciting their groups for symposia topics, papers, screening committees and moderators for their intended sessions. Should you desire to participate in helping any P.A.G. in organizing a proposed session for presentation to the Program Committee, please contact the appropriate chairmen listed below:

P.A.G.	Chairmen	Company	Address
Casting and Plastics in Tooling	Jerome D. Bassin	Borden Company	14 Johnson St. Bainbridge, N.Y.
Compression Molding	Edward W. Vaill	Bakelite Co.	30 E. 42nd St., New York, N.Y.
Extrusion	John H. Myers	Celanese Corp.	Newark 5, N.J.
Finishing and Decorating	G. K. Storin	Speer Carbon Co.	Niagara Falls, N.Y.
Forming	Lawrence D. Barr	Plax Corp. P. O. Box 1019	Hartford, Conn.
Injection Molding	Robert R. Meyer	Monsanto Chemical Co.	Springfield, Mass.
Metals for Plastic Molds	Charles Davis	Electromold Corp.	Trenton, N.J.
Plastics in Bldg.	R. Gray	Dow Chemical Co.	Midland, Michigan
Plastics in Coatings	Robert Abeles	Elfskin Corp.	Worcester, Mass.
Plastics in Electrical Insulation	Max M. Lee	General Elec. Co.	1635 Broadway Fort Wayne 2, Ind.
Reinforced Plastics	Dr. Alex Sacher	Standard Insul. Co.	74 Paterson Ave. E. Rutherford, N.J.

Please start writing now — the deadline for all briefs is April 30th.

Cordially,
Alex Sacher
Program Chairman

NEWS of the industry

Injection Molder

A ¾ ounce bench injection molding machine for use with all thermoplastics, specially designed for fast production runs, priced at 130 pounds Sterling, F. O. B., is announced by S. R. Seymour and Co., Ltd. Brook Road, Rayleigh, Essex, England. They will reply to all inquiries.

Static Eliminators

Simco Company, 920 Walnut Street, Lansdale, Pa., announces two new types of static eliminating equipment, specifically designed for cleaning dust and dirt from plastic parts, plastic and paper sheets and films, textile materials, rubber, leather and all other types of surfaces to which the dust is attracted and held electrostatically. In the new static bars, provision is made for simultaneously blowing off the dirt and neutralizing the static charges on both the dirt and the part being cleaned. This simultaneous action is much more effective than other cleaning methods such as brushing or wiping, since not only is the dust completely removed, but the electrostatic forces tending to re-attract it to the part are eliminated.

Vacuum Coaters Society

The executive committee of the Society of Vacuum Coaters met at the Sheraton Cadilac Hotel in Detroit, Michigan, on January 31st, 1958.

Following are some of the decisions made—

The annual Fall Meeting will be held at the Hotel Statler, Detroit, Michigan, on November 5th and 6th, 1958.

Those interested in presenting a paper on the technical and practical applications and techniques involved in functional and decorative vapor deposition should send a 100 word abstract as soon as possible to F. Gruen, Program Chairman, Syn-Cote Chemical Corporation, Long Island City, New York.

Membership application cards can be obtained from M. Adler, Membership Chairman, Society of Vacuum Coaters, P. O. Box 3095, Cleveland 17, Ohio. New members will receive a copy of the 1957 transactions.

Mr. T. Comer was appointed chairman of the nominating committee. Two vacancies will occur on the executive committee this Fall.

Achievement Award

The Southwest Housewares Achievement Award for "The Most Outstanding Contribution to the Housewares Industry for 1957" has been conferred on Loma Plastics, Inc. of Fort Worth, Texas for its fashionable new polyethylene clothes hamper.

Louis H. Barnett, president of Loma, accepted the coverted award from Hunter Michaels, past president of the Texas Housewares Club, at the organization's annual breakfast meeting in Chicago during the National Housewares Exhibit.

Gamma Irradiators

Isotopes Specialties Company introduces: Nucor "HERO" Series high flux gamma irradiators now available for applications from 600 hr to 3 x 10⁶ R/hr and higher. Unit is simple, safe and economical, with welded steel case and such low surface flux that it can be used in any office or laboratory without special construction or connections.

Expansion Plans

Plans to increase production facilities for its line of "Insurok" industrial laminated plastics have been completed by The Richardson Company, Melrose Park, Ill.

These plans will affect two of the Company's six plants—in Newnan, Ga., and Melrose Park—through a shift in production emphasis and installation of new equipment.

At Newnan, the production of decorative laminates will be discontinued soon to make ready for increased production of industrial laminates.

At Melrose Park, installation of the latest type phenolic saturator and a new 12-opening laminating press will increase facilities for manufacturing the Insurok laminates.

Custom Castings

Plasti-Skill is the name of a new company specializing in custom plastics castings, such as polyesters, epoxys and phenolics. They also do development and make models and production molds for vacuum forming. President is Nick George. The company is located at 102 37th Ave., Corona 68, N. Y.

Hydrocarbon Resin

The Chemicals Division of Golden Bear Oil Co., announces the commercial availability of Bearflex 1751, a low cost liquid hydrocarbon resin having high compatibility with polyvinyl choride.

Bearflex 1751 is the first of a series of products for the plastics industry to be manufactured by the Golden Bear Oil Co., producers, refiners, and marketers of petroleum products.

A blend of 70% Bearflex 1751 and 30% DOP gives a plasticizer system compatible in all proportions with polyvinyl choride resin. Physical properties compared to a 100% DOP compound are not affected appreciably; electrical properties are improved.

Bearflex 1751 is recommended for extending vinyl compounds used to produce film and sheeting, garden hose, electric insulation, profile extrusion, dip coatings, and slush-molded products. It is particularly useful for extending non-migrating vinyl compounds which contain polymeric plasticizers.

Samples and literature can be obtained by writing to the Golden Bear Oil Co., Chemicals Division, 325 West 8th Street, Los Angeles 14, California.

Bonding Polyethylene

The normally poor adhesive bonding properties of polyethylene can be improved by treating the plastic with chromic acid, according to a report of recent Army Ordnance research just made available to industry through the Office of Technical Services, U. S. Department of Commerce.

Tests demonstrated that treatment with concentrated chromic acid chemically alters the surface of polyethylene so that good peel and shear strength bonds are possible. The treatment is recommended prior to bonding whenever high-strength bonds are required.

Also evaluated were a series of commercial and experimental adhesives for bonding polyethylene. Most did not meet Ordnance Corps requirements, primarily because of relatively low bond strengths at both 73 F and 160F and generally poor flexibility and adhesion at minus 65 F.

It was observed that bond strengths of currently available polyethylene adhesives depend primarily on their permanent tact tendencies rather than on chemical reaction or mechanical interlocking with the polyethylene.

The report, PB 131099 **Bonding of Polyethylene,** W. H. Schrader and M. J. Bodnar, Picatinny Arsenal, U. S. Army Ordnance Corps, Mar. 1957, may be ordered from OTS, U. S. Department of Commerce, Washington 25. It contains 39 pages, price $1.

Industrial Literature

Government Reports

Three reports of chemical research for the Armed Forces, two dealing with copolymer studies and the third with development of an expression for thermal decomposition of methane, have just been released to industry through the Office of Technical Services, U. S. Department of Commerce.

Copolymers of 1, 1-Dihydroperfluorobutyl Acrylate with some Vinyl Silanes. E. C. Stump, Jr., Wright Air Development Center, U. S. Air Force. Aug. 1957. 24 pages. (Order PB 131375 from OTS, U. S. Department of Commerce, Washington 25, D. C., 75 cents.) There is an urgent need for thermally stable polymeric materials for use in advanced high-speed aircraft and missile systems. In this study, an elastomer was sought with high temperature resistance as well as improved resistance to the deteriorating and swelling effects of fuels and oils.

Dilute solution techniques for Styrene-Methyl Methacrylate Graft Copolymer and its precursors. R. A. Guzzi, Picatinny Arsenal, U. S. Army Ordnance Corps. Apr. 1957. 20 pages. (Order PB 131261 from OTS, U. S. Department of Commerce, Washington 25, D. C., 50 cents.) It was determined that dilute solution techniques can be adapted to the study of styrene-methyl methacrylate graft polymers and their precursors.

Development of techniques and equipment which produced a satisfactory metal foam for sandwich construction is described in a three-part report for the Air Force just released for industry use through the Office of Technical Services, U. S. Department of Commerce.

The report is entitled **Foamed Metal Low Density Core Material for Sandwich Construction.** It was prepared by J. Bjorksten, J. C. Elliott, and R. J. Roth of the Bjorksten Research Laboratories, Inc. for Wright Air Development Center. Its parts include:

Part 1. June 1952. 26 pages. (Order PB 131419 from OTS, U. S. Department of Commerce, Washington 25, D. C., 75 cents.) This project was aimed at determining whether metal foam superior to plastic foams could be produced. Preliminary work demonstrated the feasibility of foaming magnesium-aluminum alloys. Metallic low density foams were produced using either titanium or zirconium hydride as the foaming agent.

Part 2. Sept. 1953. 26 pages. (Order PB 131466 from OTS, U. S. Department of Commerce, Washington 25, D. C., 75 cents.) Work continued on the improvement of the foaming process and equipment for preparation of specified samples. The foaming procedure, in simplified form, consisted of melting the metal to be foamed, stirring in the foaming agent, releasing hydrogen from the hydride, and solidifying the foamed metal.

Outdoor Exposure

"Resistance of Plastics to Outdoor Exposure" is available as Report PB-131331 from the office of Technical Services, U.S. Dept. of Commerce, Washington 25, D. C., at six dollars per copy.

Vinyl Printing

Claremont Pigment Dispersion Corp., 39 Powerhouse Rd., Roslyn Heights, N. Y. offers a set of data sheets on inks for printing on vinyls.

Intensive Mixer

New to Stewart Bolling's line of Intensive Mixers is the No. 1-B Model for medium small production and major laboratory work with rubber and plastics. Dimensions are: overall height—11 feet; overall width (without control panel)—8 feet. Holding capacity is 1200 cubic inches. Temperature range to 500°F. Batch sizes range from 24 pounds, 1.00 gravity through 45 pounds at 2.00 gravity. This new mixer has all Stewart Bolling features which include anti-friction rotor journal bearings, split end frames, and Spiral-Flow sides which heat or cool with optimum efficiency. Found only on Stewart Bolling's largest mixers, but available on this new model, is the compound type drive which permits high rotor speeds, and power application, but requires little space. The Model 1-B is equipped with Stewart Bolling's motorized discharge door, giving fast, positive action on door openings and closing. All surfaces coming in contact with materials are chrome-plated. Designed and built by Stewart Bolling & Company, Inc., 3190 East 65th Street, Cleveland 27, Ohio.

Men in the News

William C. West, Jr.

William C. West, Jr., 38, has been elected president of West Instrument Corporation, succeeding his brother Richard K. who was lost in a recent airplane accident.

"Bill" West was one of the founders of the Chicago manufacturing firm, and had been vice president and secretary until the current election.

William A. Kelly, attorney and director, was elected secretary.

Clarence D. Bell

Clarence D. Bell has been promoted to director of sales for plastics in Du Pont's Polychemicals Department.

Mr. Bell, who has been assistant director, replaces Russell C. Weigel, who was promoted to assistant general manager of the department January 1. In his new post he will have general responsibility for the sales of Du Pont's materials for the plastics industry—"Alathon" polyethylene resin, "Zytel" nylon resin, "Lucite" acrylic resin, "Teflon" tetrafluoroethylene resin and several other plastic materials.

Alfred M. Johnsrud

Alfred M. Johnsrud of Middlesex (N.J.) has been appointed sales engineer of Frank W. Egan & Company's Plastics Extrusion Division.

Johnsrud, who joined the Somerville (N.J.) firm in 1951, was formerly a member of the engineering department.

Sollenberger and Lavely

Two new appointments in the Chemical Division of Koppers Company, Inc., George H. Sollenberger has been named Product Manager for polyethylene and Henry C. Lavely has been appointed Product Manager for expandable polystyrene.

"Lin" Love

Appointment of L. E. "Lin" Love as general sales manager, plastics, is announced by Midland Industries Limited.

Mr. Love, for the past year sales manager, industrial molding, will now direct not only the expanding operations of that division but also the sales program of the growing number of Midland's proprietary plastics items.

George M. Hale

Appointment of George M. Hale to the newly-created position of vice-president and general manager is announced by Canadian Resins and Chemicals Limited, effective January 1, 1958.

AROUND THE WORLD

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UNITED STATES
ELECTRICAL MANUFACTURING
February, 1958
Abstracter: W. A. Kelley

Evaluation and Applications of Fiber-Insulated Magnet Wire—*H. L. Saums and W. W. Pendleton*

Complete spectrum of fibrous, film and composite magnet wire insulation is reviewed as complement to previous article by same authors on enameled magnet wire (October 1957). Characteristics are listed, advantages and disadvantages of various types are compared, and applicable areas of use are listed. Insulations discussed include nylon yarn, polyester yarn, asbestos paper, glass fibers, polyester film.

January, 1958

Heat Resistant Laminate for Supersonic Airborne Equipment—*F. Jahns, Jr. Continental-Diamond Fibre Corp.*

This is a brief evaluation of new types of felted asbetosbase phenolic laminates developed to cope with the severe structural heat problems in the areas of airborne missiles, supersonic aircraft and high energy fuel and electrical systems. Various physical properties of the new laminates are tabulated.

Foamed Plastics for Structural Functions in Electronic Equipment—*R. Thielman, Jack & Heintz, Inc., Cleveland, Ohio*

Sandwich type elements made of foamed plastics can be used for such mechanical elements as mounting plates for airborne electronic equipment required to withstand severe natural and induced environments. This article analyzes design factors related to vibration, evaluates foam materials as structural and mechanical elements, and cites case histories such as the use of foam sandwich structures for mounting boards. Foam embedment is also mentioned as an additional technique.

Irradiated Polyethylene Insulation Systems—*K. J. Mackenzie and R. A. Ward*

Since their introduction in 1954 irradiated polyethylene tapes and films have found increasing use as insulation in various types of electrical equipment. This article reviews the characteristics of these materials with emphasis on electrical properties derived from new functional tests. Advantages of irradiated polyethylene include stable properties over a wide temperature range and an ability to form an encapsulated water-impervious sheath.

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MATERIALS IN DESIGN ENGINEERING
January, 1958
Abstracter: Leonard S. Buchoff

Joining and Fastening Plastic — *Malcolm W. Riley*

Solvent cementing, adhesive bonding, thermal welding and mechanical fastening are discussed in this excellent comprehensive article.

Solvent cementing is most suitable for the more amorphous and soluble thermoplastics such as acrylics, cellulosics, and polystyrenes. It is not generally useful for more crystalline, insoluble thermoplastics such as polyethylene, nylon and fluoro-carbons. Solvent cementing cannot be used for thermosets.

Suitable solvents are listed for the applicable plastics with remarks as to the quality of bond produced.

Adhesive bonding is probably the most versatile plastic joining method in the types of materials that can be bonded and the variety of service conditions for which a satisfactory bond can be developed. A chart presents the chemical types of adhesive useful in bonding a plastic to itself or any of the other plastics listed. In selecting an adhesive for a critical plastics bond a great deal of time and trouble can be saved by consulting the adhesive formulator and supplier. Design considerations and methods of applications are described.

Thermal welding is suitable for virtually all thermoplastics though particularly useful in joining the more crystalline types such as polyethylene, PVC and nylon. Hot gas welding, heated tool welding, heat sealing, induction welding and friction welding are discussed.

Mechanical fastening is suitable to all plastics, but care must be taken in designing servicable fastened joints because of possible localized stresses.

Design considerations and selection factors are given that help make this article an excellent guide to selecting the correct joining method for a particular job.

How Radiation Affects Six Organic Coatings — *Lt. L. A. Horrocks*

Ionizing radiation produces molecule fragments which recombine with each other, displaced electrons or oxygen to cause a change in the exposed coating. Phenolics retained their properties better than any of the other coatings tested under gamma radiation.

Silicone alkyd enamels rank second, failing by oxidation that causes the coating to become powdery and brittle. Next comes alkyd enamels which exhibit a large decrease in abrasion resistance and adhesion.

Epoxy coatings are severely degraded by radiation exposure, particularly the metal coating bond, which decreases adhesion. Cross linking and bond breaking degradation causes fluorinated vinyl coatings to lose their good cohesion and corrosion resistance. Nitrocellulose lacquers rank last in the tested group as shown by their porosity and poor overall condition.

Resistance of polymers to radiation can be increased by increasing electron mobility and oxidation stability. Pigments make a striking difference in radiation resistance. A table lists the effects of increasing radiation dosage on the properties of the coatings with and without fillers and after various baking cycles.

Polypropylene — A Promising New Plastic — *C. Crespi*

Isotactic polypropylene is made by means of heterogeneous catalysts which produce highly crystalline polymer of regular structure. It is stronger, tougher, has higher heat resistance, lower density and about equal chemical resistance and electrical properties as high density polyethylene.

Unstressed polypropylene parts

maintain their shape up to 300°F but become brittle at -30°F. Equipment and techniques for molding and fabricating polypropylene are generally similar to those used for handling other thermoplastics. Applications of this material will probably include moldings, sheet, film and fiber.

Charts and graphs give the mechanical, thermal and chemical properties of polypropylene.

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GERMANY
PLASTE UND KAUTSCHUK
January, 1958
Abstracter: Walter Brenner

A Polarographic Technique for the Determination of the Double Bond Content in Maleic Type Polyesters—*Dr. A. Wende*

The fast and simultaneous determination of maleic fumaric acids by means of polarography is described with the results accurate to ± 3%. The method is based on the saponification of the polyester with aquous sodium hydroxide solution. Techniques are described in detail and experimental data are presented.

Polycarbonates—a new group of thermoplastics; a brief review of recent developments.

Silicones as textile additives by Dr. R. Mueller; a fundamental review covering material well covered in American publications.

February, 1958

The Plastics Industry in the German Democratic Republic —Review and Outlook—*Dr. W. Heinrich*

The plastics industry of the German Democratic Republic has considerably increased in recent years but still lags far behind the production levels achieved in other countries including the U.S.A., Great Britain, France, Italy, etc. The two main pillars of the industry are the phenolics and polyvinylchloride type synthetics. Phenolics account for 35% of plastics production and PVC accounts for as much as 50% with all other plastics accounting for only 15 % of production. Qualitatively much is to be desired in the way of achieving better product quality standards. The principal tasks facing the industry are the modernization of both resin making and fabricating equipment, development of suitable standards, more research and development, better design, and more publicity to overcome popular feeling against "ersatz" materials.

Sterospecific and isotactic polymers by W. Schafer; an elementary review of basic definitions, etc.; Data on some Natta developed polymers.

On the meaning of silico-organic compounds as "finishing" resins for glass reinforced plastics by Dr. K. Schnurrbush; a discussion of the role of organo silicon compounds for glass fiber finishes to improve the adhesion between the glass and the laminating resins; U. S. data as to the improvements made possible by the use of such glass fiber finishes are described in some detail in Volan, Garan, and other types of glass fiber finishes.

Some experiences with halogen containing plasticizers in PVC—53rd contribution of the Institute for Chemistry, Technology of Plastics of Leipzig. Selected data on chlorinated paraffins and halogenated diphenyl derivatives as to their performance as PVC plasticizer.

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ARGENTINA
PLASTICS
December, 1957
Abstracter: John B. Ballard

Plastics News — *Editorial*

Monsanto—Atanor, S.A., which will soon change its name to Plastics Atanor, Industries Quimicas Argentinas, S.A., has completed an agreement with vinyl products, Ltd., of England, for technical assistance in entering the manufacture of emulsions and solutions of vinyls, methacrylates, and other materials for the rubber textile, leather, paper, and adhesive industries.

A new firm, Monsanto-Andes, is being formed to manufacture vinyl materials in the province of Mendoza.

January, 1958

Plastic Net by Extrusion

A short article describes a completely new technique of producing a plastic net continuously—almost all thermoplastics may be used. Photos are included.

The Use of Plastics in Latex Form—*Part I by J. Brydson*

Latices are widely used for such applications as emulsion paints, fleximer flooring compositions, adhesives, paper converting, leather finishing, and in association with textiles for a variety of purposes. In a three page article, the first of two, the nature of latices, the commercial types available, and the compounding ingredients are covered.

Graft Copolymers—*Part 3 by S. H. Pinner and V. Wycherley*

In this concluding article, a comparison of synthetic methods of grafting polymers, details of the properties of such polymers, and the possible applications are given.

Investigations on the Determination of the Acetic Acid Yield of Cellulose Acetate

This article covers the report of a Sub-committee of the British Standards Institution which was convened for the purpose of drafting a standard for the methods of analysis of cellulose acetate flake. It gives a critical examination of the various possible ways of determining the acetic acid yield of cellulose acetate and concludes with a recommended procedure.

★

FRANCE
INDUSTRIE DES PLASTIQUES MODERNES
January, 1958
Abstracter: Hans Mayer

Use of Plastic Reinforcements in the Field of Dredging — *L. Taal*

The article describes the investigation into the feasibility of the use of glass reinforced plastic pipes in dredging. The investigation was prompted by the fact that the growth of the average size vessel, using the Dutch canals, tended to interfere with the necessary dredging operations unless a lighter type of pipe for the flow of the dredged matter could be developed so that existing superstructures would be strong enough to carry the larger diameter piping instead of the present small diameter iron pipes.

It was found that almost every type of material submitted for tests, even so comparable amounts of glass and resin had been used in their construction, gave divergent test results. It was found that the strength of the product was almost entirely dependent on the glass. It was determined that the number of ends in the roving, the construction of the spools, the method of unrolling, treatment, even length of cuts etc., all had a bearing on the strength of the pipe.

Certain rules for the determination of resistance to traction in glass reinforced constructions were set up and are described.

Plastics can transform Agriculture. II Jules Soyeur.

The criteria for the use of plastic film in agriculture are: 1) its ability to permit an exchange of air and water vapors,

2) its resistance to hot and cold weather,
3) its weathering qualities,
4) its chemical inertia,
5) its mechanical resistance,
6) its ability to permit the penetration of all strata of the sunlight,
7) its workability.

It is described in length that other but polyethylene films cannot be used unless provisions are made to let air and evaporation find their way through openings in the film. The comparative qualities of polyvinyl, acrylic and polyethylene films regarding the above mentioned desirable qualities are being evaluated.

Kansas City

Electrical Applications of Epoxies

Carl W. Bontemps

The February Meeting of the Kansas City Section took place the evening of February 19th at Wolferman Restaurant on the Country Club Plaza.

Mr. Lloyd A. Dixon, Jr., native Californian, and present West Coast manager for Houghton Laboratories, Inc., Culver City, California, was the principal speaker of the evening and presented a very interesting program on "Recent Epoxy Advances in Electrical Application." Of particular interest in the talk was the fact that epoxys are finding wide use in high reliability type electronic components, for encapsulation and potting applications. The principle advantage of epoxys here is the ability of the material to keep out moisture in electrical components over a very wide range of temperature and humidity conditions. With an electrical component operating in a continuous environment of an absolute minimum of moisture without any change due to the type of encapsulation used, it maintains highest reliability under all operating conditions. In addition to this excellent property the material is also being used not only to insulate and protect from moisture but also as a structural part in both the mounting and construction of transformers, capacitors, resistors and one example was given of a non-reinforced cast epoxy used as a gear train part and in this function also served as an insulator in the electrical system. Very low shrinkage values on casting, high compression strengths in the neighborhood of 10,000 PSI at 300-350° F., excellent di-electric properties and resistance to moisture make the epoxy materials highly ideal for the field of high reliability electronic components.

A discussion was also held on the use of epoxys in tooling applications such as for short run injection molding and compression molding and also for applications in the coatings field. In these fields it was noted that because of the excellent adhesion between epoxy and glass reinforcement it is possible to have resin contents of only 19% in some cases. It was noted that 90% of the epoxy sold has been in the liquid form and most of the research is in this direction because of its ease of handling. Epoxys in the solid form are more difficult to use in that they must be heated to fairly high temperatures before hardener can be added and molding accomplished.

The meeting was attended by 23 members and guests. Mr. Jan Jervert of Copenhagen, Denmark was present as a guest; Mr. Jervert has been touring the United States learning American business procedures in the machine tool field and has been spending time in the plastics industry in the Kansas City Area.

R.I.S.E.M.

Cable Design, Past and Future

Glenn A. Tanner

The February meeting of the R.I.S.E.M. Section was held at the Tops Gaylord restaurant in Providence, R. I. on February 27th. Due to the inclement weather, the turnout was small to initiate the new meeting place and to hear Mr. Jack Burroughs of E. I. du Pont speak on "Cable Design, Present and Future".

Everyone of the 33 members present seemed pleased with the facilities of our new meeting place. There is a less crowded atmosphere with a larger room, a private coat room and bar available for the members, and individual tables to promote congeniality. If all of their meals compare with the steak they served members at this meeting, the new establishment should meet with the approval of all our members.

The meeting was called to order by Mr. Charles Chrones of Hassenfeld Brothers, Providence. Mr. Robert Johnson of Monsanto Chemical Co., and National Director, reported on the National Meeting in Detroit in January. He also offered the suggestion that, since our section is drawing from not only Rhode Island and south-east Massachusetts area, but from eastern Connecticut and central Massachusetts, as well, that the name of our section be changed to the Southeastern New England Section. After discussion, a motion was made to this effect and seconded and passed almost unanimously. Mr. Johnson will take the matter before the National Council and check on the necessary steps.

Mr. Sydney Lohman of Lester-Phoenix Corp. and Chairman of the Ladies Night Committee, announced that our annual Ladies Night will be held May 22nd at the Pawtucket Country Club. Committees are established for this annual event and we are looking for an excellent turnout as usual.

Mr. Edward Rose of Plastic Engineering Corp., Pawtucket announced the passing of Mr. William Dunnican. Mr. Dunnican was one of the founders of our section and his death is a great shock to all members.

We were very honored to have Mr. Jack Burroughs, Program Manager of Wire and Cable at E. I. du Pont speak to us as a replacement for one of his subordinates, who had taken ill. With very interesting and appropriate slides, Mr. Burroughs presented excellent comparisons between past designs of all types of cables and wire and current or future designs that are possible with the increasing use of plastics, such as PVC, polyethylene, flame retarding polyethylene, nylon.

He showed how these new materials are replacing everything from the old rubber and fabric covered wires, which are common in every household, to the much more complicated telephone cables, which formerly were prepared from paper and lead coverings. He demonstrated how these changes affect not only the other dimensions of the wire and cables, but their durability and weight as well.

Our President, Mr. Charles Chrones donated two door prizes, which were won by Mr. Maurice Chafitz and Mr. Kenneth Clark.

Miami Valley

Plastic Sockets; Lexan are Topics

Leo T. Kruskamp

Two speakers were featured at the February 6 meeting of the Miami Valley Section. In an attempt to cover a broader field and thereby keep the members better informed of new developments and attract more members to the meetings, the Miami Valley Section has started a program of two speakers at each meeting.

At the February meeting held at the Wishing Well at Centerville, Ohio, the double-barreled program attracted a capacity audience.

The first speaker, Mr. R. J. Thompson of General Electric Chemical Division, spoke about their newest plastic family, the Lexan Polycarbonate Resins.

1) This is a new thermo-plastic material particularly outstanding for its high heat resistance. (280 to 290°F heat distortion point)
2) Its impact resistance. (12 to 14 feet pounds per inch of notch)
3) Excellent dimensional stability.
4) Good electrical properties.

Lexan is now being produced in pilot plant quantities at Pittsfield, Massachusetts. Numerous tests are now being made in varied applications such as coil forms, gears, radio housings, and cans. The results to date are very promising. General Electric expects to be producing Lexan in high volume some time in 1959. Since this is a completely new family of thermo-plastic materials, they feel that their unusual properties will open many new applications for which no present plastic has been found suitable.

The second speaker of the evening was Mr. Richard Liday of the Inland Division of General Motors Corp. Mr. Liday presented the complete story of the development of molded plastic sockets for ball joints. When design engineers first proposed the ball joint as a replacement for the king pin in the automobile suspension system, the engineers at Inland began a study of a plastic socket to be used with a hardened steel ball. Nylon and other thermo-plastic materials were tried but failed in field tests. The high impact applied to this joint when an auto passes over a chuck hole and the abrasive dirt that works itself into this joint prove to be too tough an obstacle for the thermo-plastic materials. Reinforced phenolic was then tried. The problem of bonding the phenolic to a metal backing plate was solved by using one layer of laminate impregnated with a cement that would cure at the same pressure and temperature as the phenolic laminates. The low coefficient of friction was made possible by the addition of 10% graphite in impregnating the laminate.

Field tests are made in which the plastic socket must hold up for 25,000 miles without failure and show evidence of an additional 25,000 miles potential. Quality control tests are made of compressive stress, friction, and abrasion resistence. The test for abrasion resistence is made by using a lubricant containing an abrasive and moving the ball joint through a specified number of cycles.

West New England

Extrusion Forum

C. Judd Holt

Seventy-nine members and guests attended the regular monthly dinner meeting on March 5 at Betty's Towne House, Agawam, Mass. It was extrusion night. Lawrence W. Freeman (Plax Corporation) was technical chairman.

There were two speakers. Dr. James F. Carley, engineering editor of Modern Plastics magazine, New York and Robert D. Sackett, technical service associate for Monsanto Chemical Company's Plastics Division, Springfield, Mass.

Carley discussed the relationship of extrusion and molding and reviewed the advantages and disadvantages of combining the extrusion and injection molding operations in a single machine.

Sackett, who is an extrusion specialist for his company, spoke on recent developments in his field and reviewed some of the extrusion papers which were presented at the 1958 ANTEC.

Blakely R. McNeill, Fuller Brush Company, general chairman of the section's regional technical conference on "Plastics in Packaging," which is scheduled for October 1, 1958, announced the following committee chairmanships.

Co-Chairman, program and speakers committee, Eli A. Haddad, Monsanto Chemical Company, and Robert R. Moyer, Monsanto.

Chairman, house committee, Armand J. Vallieres, Pro-phy-lac-tic Brush Company.

Chairman, registration committee, Lawrence W. Freeman, Plax Corporation.

Chairman, publicity committee, C. Judd Holt, Monsanto.

Treasurer, Alvino Aliberti, A and M Tool and Die Company.

McNeill also reported that a letter soliciting papers has been sent to all sections of the society.

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Binghamton

New Lecture Equipment Bought

Leo J. Pranitis

A tremendous turnout of members and guests at the Hotel Carlton on the evening of February 27th heard Mr. James Owens of the du Pont Sales Division speak on the new thermoplastic resin: "Delrin". The topic was extremely well presented by a very well informed Mr. Owens and accompanied by about sixty 35-mm. slides illustrating the structure, chemical and physical properties, molding, processing, machining, and testing of Delrin. Several sample moldings of the new acetal resin were exhibited by the speaker throughout the talk and each person was presented with a pocket comb molded of Delrin.

An added attraction of the evening was the display of the new equipment just purchased by the Section. These speaking aids consisted of a 30-watt amplifier, portable microphone, two 12-in. speakers, an automatic 35-mm. slide projector, and a 70" x 70" screen.

Our president, Emery Slaght, announced that plans are being drawn for the Section's 2nd Annual Dinner Dance to be held on May 17th at the Hotel Carlton in Binghamton.

Mr. Frank Reynolds, our Natural Director (and just recently appointed National Membership Chairman) spoke to the group on the activities of the National Council during the recent ANTEC in Detroit.

The next meeting was held at the Vestal Steak House on Thursday, March 27th and Joseph R. Venne of IBM Corp., the speaker of the evening, discussed "Tooling Cavities for Quality Class Commercial II Spur and Helical Plastic Molded Gears."

Southern California

Adhesives is Topic

John A. Stahmann

Mechanical fastenings, such as rivets, were acceptable during the period of metal's supremacy, but todays' adhesives can take on just about any job, Mr. Middleton reported. Resinous adhesives can adhere the thinnest films and the heaviest structures. They do their job faster, better, and more economically than older methods.

This was the theme of Mr. J. C. Middleton's talk to the Southern California Section of S.P.E. Mr. Middleton is associated with the adhesives, coatings, and sealers division of Minnesota Mining and Manufacturing Co. As supervisor of Aircraft Technical Service, he drew on a varied background and professional knowledge.

Adhesives, as used today, are actually the "third dimension in design". The modern design engineer considers four stress loads, namely; tensile, shear, cleavage, and peel. These are inter-related to some extent.

The selection of a proper adhesive has many other criteria than that of the type and magnitude of the stress to be met. Exposure to chemicals and weather may be the prime factor in design. Fungi and bacteria action are possibilities. Perhaps a high initial strength is required.

Application methods and assembly difficulties must be foreseen. Should the adhesive be a liquid or a paste? Will clamping be necessary? Must the unit be heated and can it withstand temperatures? What are the curing conditions allowable?

Newark

Rotary Molding and Mold Casting

Fred W. Ducca

The members of the Newark Section met on February 12 for the regular monthly meeting at the Military Park Hotel. At this meeting two very informative presentations were made; one concerning rotational molding and the other relating to the casting process for mold parts. Both currently have considerable interest to the molding trade.

Mr. F. A. Miller, president of the Akron Pressform Mold Company, reviewed the general history of the development of rotational molding equipment. The first commercial molding machines were offered to the trade in 1952 and are based on the use of polyvinyl chloride plastisols. Since that time there has been a steady growth in the use of rotational equipment. At the present time it is estimated that about 60 plants are using this technique. Rotational molding equipment has been supplied to manufacturers in Europe, South America and Australia.

It was pointed out that rotational molding is easy to use; however, the plastisol must have the correct gel rate and the machine must be properly adjusted. This type molding is ideal for the manufacture of hollow items. It offers excellent control over cross sections, surface quality, detail and weight — problems that are inherent in the slush casting process that was its predecessor. Typical items that are made by this process are toys, artificial flowers, hobby horses, dolls, etc.

The second speaker for the evening was Nick Metrocavich, of Newark Die Hobbing and Casting Company, who described the Shaw process of casting mold components. This is a method of investment precision casting without the use of expendable patterns.

For this process, a model or pattern is first made out of any solid material that will take a high finish and can be worked easily, such as brass, plastic, steel, etc. A slurry is then made of high grade facing refractory mixed with ethyl silicate and a jelling agent. This is then poured over the pattern. Next, a slurry of coarse refractory is poured in to fill the remainder of the mold. In setting up, it will pass through a rubbery state and at this time it is stripped from the pattern. The Shaw is then ignited by torch to burn off the jelled binder. Next, the Shaw is put in a furnace to be baked out at a very high temperature. The result is a strong, finely porous mold which will allow the gases entrapped in the mold to escape when the molten steel is poured into it.

After this, a head is made for the Shaw mold in the same fashion as the Shaw itself. The head and Shaw are then luted together to form a complete mold ready for casting. Steel or whatever alloy is desired is then poured into the mold and the mold allowed to cool. After two hours the Shaw is broken to release the casting which is then machined and polished. Mr. George Ruddin illustrated the various steps in the process with parts supplied by Newark Die.

Southern

The Plastics House

Sam Rutland

The meeting was held on February 17, at the Architects and Engineers Institute Building, 230 Spring Street, N. W., Atlanta, Georgia. We enjoyed the company of the wives of many of our members and guest for a very special program.

Mr. Ralph Hansen of Monsanto Chemical Company presented a delightful and informative talk on Monsanto's all plastic "House of the Future." Mr. Hansen supported his talk with slides and carried us through the various stages of development, testing and construction of the house. Our lady guests were enchanted by many of the amazing utilities; the men, though amazed, seemed a bit worried about how expensive this program could be in the future.

Our program chairman announced a very interesting plant tour to Owens-Corning Fiberglas at Anderson, South Carolina, for our next meeting on March 17.

Syracuse

Officers Elected

Anthony Falcone, Jr.

The Syracuse Section of the Society of Plastics Engineers received its charter at the annual meeting of S.P.E. in Detroit.

At the February meeting of the Syracuse Section it was announced that the following officers were elected:

Mr. James Lampman, General Electric Co., President. Mr. A. E. Krawcek, Crouse-Hinds Co., Vice President. Mr. Norman Berg, Syracuse Ornamental Co., Secretary. Mr. John S. Mills, General Electric Co., Treasurer.

The Speaker at this meeting was Mr. Ernest J. Csaszar of the Newark Die Co. His subject was "Molder-Moldmaker Relationships", showing the responsibility of the molder and moldmaker in designing and building a die. Also on the same program was a film presentation and commentary by Mr. Robert Bunker of the Dow Chemical Co. on "What Happens Inside the Injection Mold."

Milwaukee

"Delrin" Properties Are Described

James S. Hearons

The February meeting of the Milwaukee Section was held February 18 at the Bavarian Club at 6:00 P.M., dinner included. The turnout was excellent with about 50 members and guests in attendance. Future meetings will be held at the Bavarian Club at 6:00 P.M. on the third Tuesday of each month.

The meeting was opened by Tom Hardeman, President, with a short business discussion and introduction of the officers and committees for 1958.

Joe Stewart, Program Chairman, then introduced the speaker for the evening, Mr. Larry Miller, Sales Technologist for the E. I. du Pont de Nemours and Company, Wilmington, Delaware.

Mr. Miller's talk, "Delrin—du Ponts New Acetal Resin" was the first such presentation to be given to an SPE Section on this new product. The interest in the new product was quite intensive as shown by both the large attendance and the questions afterwards. The presentation dealt mainly with the properties of Delrin against other thermoplastic resins and its applications. Some of Delrin's excellent properties discussed and tied into end applications were: excellent dimensional stability; low water absorption; good abrasion properties; good tensile strength and stiffness; high resistance to creep; low coefficient of friction; fatigue endurance; toughness; chemical and solvent resistance; good color ability and high gloss. du Pont expects this new material to be available in early 1959.

We certainly feel that any members who missed this presentation really missed something and we certainly hope they can make the forthcoming meetings.

Eastern New England

Plastics in the Shoe Industry

H. C. Cookingham

The February meeting of the Society was held at the Hotel Beaconsfield on Thursday, February 20th. The topic for the night was "Molded Plastics in the Shoe Industry" and featured Mr. Carl Seibert of Eastern Plastics Company, and Mr. Les Ewing of the National Heel Company of Haverhill, who spoke on "Plastics for Women's Shoe Heels." Mr. Murray L. Aibinder of the Foster Grant Company in Leominster, presented a paper on "The Applications for Nylon in the Shoe Industry." Completing the program was a short film on "The Injection Molding of Shoe Bottoms" which was prepared by the United Shoe Machinery Corporation.

Mr. Ewing and Mr. Seibert discussed the materials and methods for injection molding and finishing of plastic heels for women's shoes.

Mr. Aibinder discussed the increasing use of nylon materials for heels. He discussed also the physical properties of Nylon 6, which is a product which Foster Grant has recently started in production. Also included was a description of fatigue test to simulate walking on shoe heels. Concluding the program was a comparison of nylon and other commercial materials used in shoe heels.

Mr. John Bergrenn of United Shoe Machinery was present to answer questions on the injection molding equipment which had been developed for the injection molding of shoe heels. Of particular interest was the fact that the most successful materials developed to date are based on polyvinyl chloride resins.

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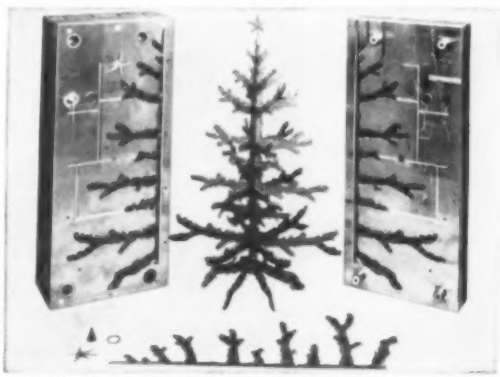

Mold for Northern Industrial Chemical — Parts for Shirley Products

When you use cavities made by the Shaw Process Casting Method you can count on saving three ways. You save time, material and money.

With an accurate model, Standard Tool can make precision cavities, cores or hobs—there's no limit size or design. Casting may be made from beryllium copper or steel.

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Illustrated is an example of an intricate single cavity mold made by the Shaw Process Casting Method. The beryllium copper matched cavity was quickly made—without high machining costs.

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Detroit

Cast Cavities in the Plastics Industry

Mac Nichols

After the most successful Annual Technical Conference ever held in the history of the Society of Plastics Engineers, the hosting Detroit Section, still bustling with enthusiasm, swung into its series of local technical meetings with unparalleled drive and earnestness.

Over 60 members and guests assembled at Stauffer's Northland on Monday February 17 to spend a rewarding evening with Mr. Irwin Lubalin, General Manager of the Shaw Process Development Corp. of England who discussed "Cast Cavities for the Plastic Industry".

Mr. Lubalin told the intent gathering that the new process was a distinct aid to the plastic processors as it enables the producing of precision cast cavities and cores in any type steel desired, as well as aluminum and beryllium copper.

"The most salient point in the process," declared Mr. Lubalin "is the elimination of the costly master hob normally used in the fabrication of cold hobbed cavities and pressure castings. In its place is the substitution of an inexpensive pattern which can be made of wood, plaster, plastic, white metal or any easily machinable metal such as brass or aluminum."

The patterns or models are invested in a special ceramic material that is kiln fired after the pattern is removed. This expendable mold is then utilized and the molten steel is poured into it under hydrostatic force and allowed to cool.

The resulting castings produce a surface finish that is superior in most cases to that obtainable from a machined cavity and enables the fabrication of cavities and cores in steel that would entail many hours of machine and bench time in order to prepare it for production.

If the shrink factor of .016" to .018" per inch is taken into consideration in the pattern, dimensional tolerances of .003" per inch can be achieved in the production steel castings.

With the able assistance of Al Milligan, Mr. Lubalin produced a ceramic mold from an existing pattern during the lecture, and passed it among the group for their inspection.

At the present time, many successful production programs are being run in thermoplastic and thermosetting materials as well as in the zinc and aluminum diecasting fields with cavities and cores made by the Shaw process. It was revealed that the prices of the precision castings made by this method are approximately 40% to 60% cheaper than those machined from forged steel blanks with delivery of the Shaw castings in any castable material being made in two to three weeks.

A movie depicting the progress that is being made in the construction of the St. Lawrence Seaway took up the opening twenty minutes of the well planned program.

Pioneer Valley

Die and Tool Forum

Gerald E. Berlyn

Three points of view were established by a panel of qualified die designers at the February 13th meeting of the Pioneer Valley Section.

Robert Ward, Improved Machinery Corporation, was moderator of the panel consisting of Ray David, Jr., Celluplastics Corporation, James Gardner, Modern Tool & Die Company and Ted Underwood, Standard Tool Company. Their subject was "Mold Design and Tool Cost vs. Molding Profits".

Mr. David approached the subject from the viewpoint of how a die customer should select his moldmaker. Major considerations are the reputation and facilities of the moldmaker and the type of mold desired.

Mr. Gardner stressed how proper selection of steels and utilization of new materials can cut mold maintenance and down time. By keeping records of mold performance, one can evaluate the various steels used.

Mr. Underwood commented on the plight of the moldmaker who must frequently quote on molds without complete information. Savings are possible if more thought is given in the design stages of the die. In order to render this service, there must be complete understanding between moldmaker, die designer and molder.

The panel answered questions from the floor. Mr. Sigmund Czarnecki, Worcester Moulded Plastics Company, started a lively discussion when he questioned the responsibility of the moldmaker to get enough information to build a good mold. The subject for the March meeting of the Pioneer Valley Section will be Sheet Forming.

Connecticut Section

Panel Discussion

Tom Hamilton

At the February meeting, the Connecticut Section had its annual 'panel discussion'. This is really a 'stump the experts' program, in which William Coughlin (Naugatuck) acted as moderator, and his panel of experts was William Smith (Waterbury), Milton Sanders (Conn. Plastics), and David Mersey (Multiplastics). The subject was choice of materials, and questions were submitted by all the members present. Cash prizes of fifteen, ten and five dollars were awarded for the three best questions.

Most interest developed in the field of polyethylene. The winner was Clifford B. Robinson (Calco), with the following . . . the many suppliers (we have lost count) of polyethylene have introduced innumerable formulations, a new nomenclature, and new characteristics, such as, melt index, weight average molecular weight, molecular weight distribution, linearity, chain branching, etc., all of which leads to much confusion on the part of the molder or extruder. Question a . . . is it possible to obtain the identical material from more than one supplier? Question b . . . where does this leave the designer and/or buyer?

Second prize went to Emil Czerwinski (Augusta Plastics), with . . . is anything being done toward clarifying the terminology and giving a positive description to the new polyethylenes.

Third prize award went for a question on tool design. In designing and building a set of tools, establishing proper shrinkage factors may be a very costly operation. Why can't the material supplier furnish the molder with more precise data than has been the case heretofor?

Kent W. Smith Elected Impco Vice President

Improved Machinery Inc. announced today the election of Kent W. Smith as Vice President. Mr. Smith, who has been Treasurer of the company since January, 1949, and a Director since September of that year, became associated with Impco in March of 1942 as Office Manager. In February of 1943, he was elected Comptroller, and in January, 1946, he became Assistant Treasurer.

Succeeding Mr. Smith as Treasurer of the company is Allan M. Barker, while Gilbert Bucknam becomes Comptroller and Assistant Treasurer.

Northwest Pennsylvania

Plastics for Lighting

John C. Reib

Mr. Robert C. Way, Section President, presided at the meeting and introduced the three speakers for the evening who were as follows: Mr. Robert A. McCarthy, Technical Service Department, Monsanto Chemical Company, Springfield, Massachusetts; Mr. Richard J. Thompson, Specialist–Sales Development, General Electric Company, Pittsfield, Massachusetts; Mr. Robert E. Stabler, Polychemicals Department, DuPont Company, Wilmington, Delaware.

Mr. McCarthy's subject was "Choosing Plastics for Lighting Applications". He cited the great growth of plastics in the lighting field in recent years. He then pointed out that prior to actual material development, suitable accelerated aging tests had to be developed to similate the effect of fluorescent lighting on plastic materials.

Lustrex Perma-Tone Styrene was then developed and this has two to three times the ultraviolet light stability of general purpose styrene. He covered applications of this material such as fluorescent "egg crate" louvres and panels and pointed out that material is also used for yellowing resistance on aging in crystal advertising displays, applicance control panels and point of purchase racks. Lustrex perma-tone styrene is economically available in crystal clarity and a full range of translucent colors.

Mr. Thompson used 35 mm. slides in his talk on "Lexan", a new thermoplastic material developed by General Electric Company. He covered the physical properties of Lexan and described the composition. He displayed comparison charts of properties of this material and other commonly used plastics. Mr. Thompson outlined injection molding conditions and applications and pointed out that the combination of properties, high heat resistance, high impact strengths, dimensional stability (low water absorption) and good electrical properties are most outstanding in Lexan. This offers a great potential for many applications. Lexan is not yet in commercial production but will be available, both clear and in colors.

Mr. Stabler discussed DuPonts Teflon 100–X FEP–Fluorcarbon Resin. Teflon 100–X is a new melt processable material which can be extruded, compression, transfer or injection molded with conventional equipment. Mr. Stabler showed slides covering properties which indicated the material would be capable of continuous service at 400°F. It has excellent dielectric characteristics which are constant over a wide range of frequencies and temperatures. He discussed applications molding processes, elaborating on injection molding techniques. Teflon 100–X is available in pilot plant quantity for development use.

Many questions from the floor directed to each speaker indicated the extreme interest in this area in new material development.

SPE Technical Meetings

See page 9 for the meeting places and times of 6 SPE Regional Conferences

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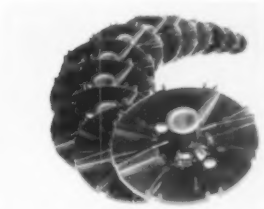
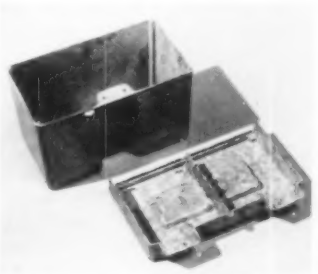


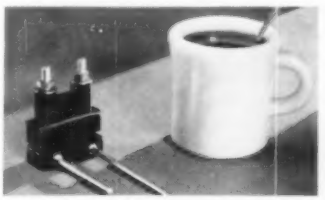
Auto maker slashes cost with phenolic

Substantial reductions in weight, production time, and cost resulted when Ford Motor Co. switched from cast iron to fully automatic compression molding, using Durez phenolic, for this 4¾-inch water-pump impeller. *If a switch to phenolic might cut your manufacturing costs, ask for our booklet on "Durez Phenolic Molding Compounds" or see your custom molder.*



High-impact case protects "flying saucer"

This housing protects the parachute of a radiosonde, Air Force device that transmits code reports on temperature, pressure, humidity when dropped from a weather reconnaissance plane. The case, which must withstand high impact and extremes of temperature, is molded of *Durez 16771 Natural. For technical data on this special-purpose phenolic, write us.*



Coffee can't affect this GP phenolic

Durez 791 Black, used in this coffee-maker component, shrugs off chemical attack of hot coffee; won't stain or deteriorate. It also has excellent surface finish and good dimensional stability; resists cracking when molded around large inserts, and is cool to the touch. *For details, write for technical data on Durez 791 Black.*

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HOOKER ELECTROCHEMICAL COMPANY
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Automatic Molding . . . .

(Continued from Page 47)

Limitations

Limitations of automatic molding, when using conventional machines on automatic molds, depend largely on the tool maker and the money which the customer is prepared to invest. To use this system the part must be maintained on the moving half of the mold without fail and yet be ejected consistently with flush type pins. A consistent means of degating must be developed. The part must either have a large enough surface area to be ejected by an air blast or must be large enough and have the proper contour to be knocked out by a sweeping arm attachment.

The limitations of the automatic machine with a conventional die are fairly well defined. The main requirement is that the parts stay either on the moving or fixed side consistently either through the use of undercuts or hold-down pins. Undercuts can either be put on the part or put on knock-out pins which are buried in the piece. The pins must be so placed that a stripper comb can move around them and get under the piece or over the piece as the case may be. If a stripper ring is used the comb can be used to push the parts from the die. Decorative parts, which cannot be dropped down a chute even though it is padded, cannot normally be molded automatically. Even if they can be molded and removed from the machine like the vertical 2 ounce machine on a controlled basis, they still must go into a handling operation for packing or further finishing. There may or may not be advantages in doing this type of work automatically depending upon the particular part and production requirements in question. Family molds do not normally lend themselves to automatic molding complete with degating since a separation problem arises. Several different parts, such as different numbered calculator buttons, can be separated satisfactorily. However, this is impossible on a toy if many parts are molded at one time. Some of the toy parts molded in family molds should be left on the sprues and runners so they can be easily racked for vacuum metallizing.

There are continual new developments in automatic injection molding equipment. One recent project being considered is taking the sprue as it is discharged in a separate chute from the press and delivering it immediately to a grinder. From the grinder the material is then pumped back into the hopper and remolded. This not only avoids a contamination problem but eliminates further labor, and may in the case of nylon, eliminate certain drying procedures. ★★

"Delrin" . . . .

(Continued from Page 36)

extruder operation and should not be regarded as best for all cases. If unusual extruder requirements are to be met it may be necessary to modify this design. For example, when extruding through a die which offers exceptionally high resistance and requires the generation of great pressure, the operation would be made easier by using a screw of shallower channel than has been indicated.

When metering type screws of the dimensions suggested here are used, heavy screen packs usually are not necessary; however, a light screen is used to break up the rotational flow of material.

The polymer has been extruded through standard dies such as profiles, tubing dies, pipe dies and wide sheeting dies. The die and adapter systems should be carefully streamlined and every effort should be made to avoid all areas of possible localized hold-up. Sharp corners, unnecessary joints and dead pockets must be eliminated. Seams and joints in all die assemblies must be carefully tightened to prevent penetration of the resin into such cracks and openings. Dies built without the necessary care or with improper maintenance can cause localized discoloration and decomposition of the resin. Figure 22 shows some of the more common design and maintenance features which can lead to localized hold-up areas and consequent difficulties.

Heater bands on the die bodies should be located in such a way that heat can be applied evenly to all portions without localized overheating. It is often desirable to insulate the die with glass wool in order to keep temperature differences in the die body at a minimum.

Standard take-off equipment, such as cooling troughs and conveyor belts can be used as with any other thermoplastic material. However, since the resin has a very rapid solidification rate it is necessary to have the equipment in good operating condition and adjusted so that the melt is not deformed during take-off.

In general, the barrel heaters are set for 390-400°F along the entire length of the barrel. These conditions have been found to give stock temperatures of approximately 390°F which have been satisfactory for most general extrusion runs that have been made. In certain cases, such as paper lamination or the extrusion of very thin film, it might be desirable to operate at a slightly higher temperature. It is recommended that the adapter and the die be maintained at the same temperature as that of the stock and that they be insulated with glass fibre or some other insulation to minimize heat losses. ★ ★

Ref: 1 E. C. Bernhardt, S. P. E. Journal, November 1955

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Pioneer Valley

Vacuum Form Process Topic

Gerald E. Berlyn

Among the newer techniques for fabricating thermoplastic materials is vacuum forming. This is a deceptively simple process to which new technology is being added rapidly while vast areas are still to be explored.

The two able speakers at the March 13th meeting of the Pioneer Valley Section, Mr. Wayne Gross and Mr. B. A. Stratton are pioneers in the development of the process and shed much light on the progress of the industry to its present state. Mr. Gross is Chief Products Engineer of A. C. Gilbert Company. He related the history of A. C. Gilbert's entrance into the vacuum forming field and explained the pros and cons of Blister Packing vs. Skin Packing. Mr. Gross had some fine examples of skin packages in the novelty field and demonstrated the appeal and economy of the process.

Mr. B. A. Stratton of Auto Vac Company next spoke of the major applications for vacuum formed products. The greatest success has been achieved in the refrigerator industry where vacuum forming has replaced injection molding of large door liners and refrigerator parts. Mr. Stratton emphasized that this is the only industry where vacuum forming has become competitive with injection molding to such a degree.

The lighting field of ceiling panels as well as wall panels, siding, wall and ceiling tile, are rapidly expanding markets for vacuum formed products. The automotive industry represents a vast untapped potential market for vacuum formed products. Among the more dramatic examples of this is a dashboard cover which has been developed for vacuum form manufacture. It had previously been shaped by hand with a 20% reject rate. To illustrate the wide interest in vacuum forming, Mr. Stratton claims that he sees 6-8 new applications per week from 50 different industries in 35 different materials.

Newer developments in the field include hot plug forming for intricate dies and molds where thinning at the corners is a problem; blow or air cushion plug molding for deep draws and complex cross-sections; and vacuum forming of laminated sheets. Where abrasion resistance is required in a finished product, a 1 mil polyester film is laminated to a polystyrene or copolymer sheet and the laminate is then vacuum formed. The polyester film puts a tough surface on the finished part.

Profits in this field are not always large because of the relatively high cost per pound of the raw material. There are areas, however, where vacuum forming is quite competitive on both large and small quantities.

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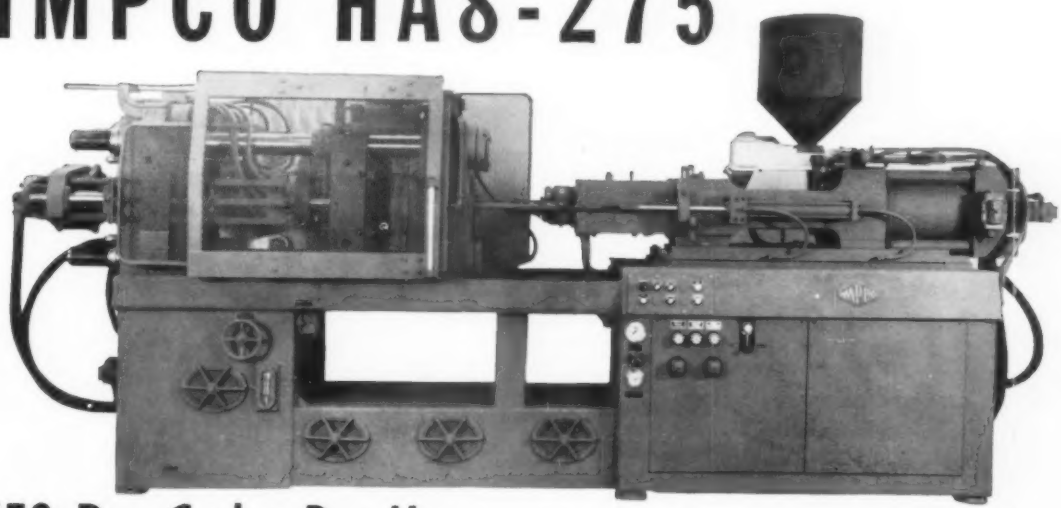

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Plastics Research . . . .

(Continued from Page 48)

to outstrip a competitor who had no research department. But today the battle is at least as much a matter of competition between the research teams of competing companies as it is between their producing, marketing and financing groups.

If all groups interested in the success of a company are working together in common understanding, then the requirements and opportunities for research will be known to all, and the company will find it easier to achieve its over-all objectives.

It is most important that the company management as a whole should take a very considerable share of the responsibility for selecting research projects. Once a decision has been made, it should not be changed without very good reason. Nothing destroys research morale in industry more than failure to implement a scientifically successful research for reasons which might have been foreseen before it started. A vacillating policy which causes researches to be dropped or restricted before there has been any change to see where they might lead is equally discouraging.

Selecting and defining objectives is one of the best ways of controlling research without destroying individual initative. Selection of projects from a list of things that need to be done and fixing research priorities must be based on a whole series of calculated risks, involving the importance of the results to the company, the amount of effort required to achieve them, and the probability that the work will be successful. If this is done properly, the research programs will be directly related to the needs of the company for results, and the chances are greatly improved that successful research will be of real use to the company.

We are now being advised that an investigation of our scientific establishments is to be made and that a crash program is to be initiated in the field of rockets and missiles. This prescription, as is usually the case with very simple ones, has serious defects. One is the common American delusion that anything can be had for money. That faith is no more misplaced than it is with respect to creative imagination. This is not a commodity in abundant supply to be had for a price. ★★

Creep in Polyethylene . . . .

(Continued from page 24)

a true picture of the long-term creep properties. Very few such tests have been made, and practically none at elevated temperatures, and it is hoped that further work will be done so that safe design limits will be available. One source of creep data has indicated that loads as low as 100 p.s.i. might be the maximum safe load at room conditions. Carey suggests (2) loads in the range of 100 to 300 p.s.i, depending on melt index and temperature, for low to intermediate densities. These are certainly mild conditions compared to the popular conception of loaded parts at sterilizing temperatures.

A second example, which is used to compare this creep information with that of high impact polystyrene, involved the proposed use of food liner supports punched from extruded polystyrene sheet. A test cabinet was assembled using such supports, and was stored with a load at a temperature around 135°F. The cabinet was unloaded and given a transportation test, and then the supports were removed and examined. Each mounting hole was elongated, showing considerable creep.

Because of this test a brief creep study was made on an impact polystyrene to get a comparison to the polyethylene curves. The results are shown in Figure 4, superimposed on high density polyethylene results under the same conditions.

It should be noted that the slopes were greater for the polystyrene even though the initial deflections were considerably smaller. Relative slopes of these curves are .651 and .657, again quite constant.

Two other things should also be noted. One is the greater effect of temperature on the elongation of the polystyrene. The other is that this material did not give a good straight line over the time interval, and the curves had a rather definite convex shape. Consequently these, too, must serve only as a crude guide to the long-time creep performance of the material.

In addition to the long-time creep and stress-rupture information on high density polyethylene which is needed for intelligent engineering design, there is another step which must be taken. This is the establishment of a short-time test which could serve as a control test on a material or part. The curves presented here might well be correlated with long-time creep data in such a way that a certain slope or a certain strain at a given time would indicate either a safe application or an ultimate failure.

Answers to these two problems will permit the use of high density polyethylenes in some engineered items, and will prevent mis-applications which give the plastics industry frequent black eyes. ★ ★

(1) Findley and Khosla, "An Equation for Tension Creep of Three Unfilled Thermoplastics", S.P.E. Journal, Volume 12, Number 12, pp 20-25, Decem-1956.

(2) R. H. Carey, "The Creep and Stress-Rupture Behavior of Polyethylene Resins", A.C.S. meeting, September 1957.

Letter to the Editor

SPE Journal
Athens, Ohio

Dear Mr. Day:

We have read with considerable interest Mr. Wurtzell's article on "Vinyl Compounds for Extrusion" printed in the *SPE Journal*, February, 1958. We feel that there are several erroneous statements which should be corrected.

On page 48 under "Typical Formulations" in the second paragraph reference is made to A-26 plasticizer with a statement that it is an *azelate* plasticizer. This is undoubtedly a typographical error and should be *adipate* plasticizer.

Further on in the second paragraph under "Typical Formulations" reference is made to our Santicizer B-16 plasticizer as one of the phosphate types. Santicizer B-16 is not a phosphate, it is butyl phthalyl butyl glycolate.

Howard S. Bergen, Manager
Plasticizers Sales Department
Monsanto Chemical Company

Iver G. Freeman

Iver G. Freeman, known throughout the industry for his development work on plastics injection machinery, has been named vice president in charge of research and development programs for the Reed-Prentice Division of Package Machinery Company.

Mr. Freeman joined Reed-Prentice Division as a vice president when it first became a subsidiary of Package Machinery in 1954. A native of Fitchburg, he was with Norton Company for 37 years during which time he rose to become works manager. He has been responsible for many product developments in connection with plastic injection molding machinery, die-casting machinery and medium-sized lathes.

He is a member of the Society of Plastics Engineers, American Society for Metals, the Society of Tool Engineers, and the Worcester Engineering Society.

Emil R. Gazdik

Emil R. Gazdik, formerly sales engineer for Evans Winter Hebb Inc., has joined the Automatic Molding Machine Co. division of Wagner Brothers Inc., Detroit, as Eastern regional engineer, F. M. Mansfield, vice president in charge of sales, announced today.

A chemical engineering graduate of Fenn College, Cleveland, Gazdik has been associated with the plastics industry 24 years. He began his career with Bakelite Co., New York, in 1934, joining Evans Winter Hebb in 1948.

John N. Pattison

Dr. John N. Pattison has been appointed director of research and development for Girdler Catalysts in the Chemical Products Division of National Cylinder Gas Company.

Dr. Pattison was formerly head of the Catalyst Research Section of the Cities Service Research and Development Company, Lake Charles, La., where he organized that firm's research section which engaged in the development of new catalytic refining processes and the improvement of existing ones.

James L. Harvey

Appointment of James L. Harvey to the position of manager of reinforced plastics development at Marion, Indiana, has been announced by The General Tire & Rubber Company's industrial products division.

Formerly president of Plumb Chemical Corporation in Philadelphia, Harvey has also been associated with the Thermaflow Chemical Corp., Atlas Powder Company and Allied Chemical & Dye Corporation.

A member of The Society of Plastics Engineers, he is a graduate of Syracuse University. He earned his master's degree in chemistry at Pennsylvania State University.

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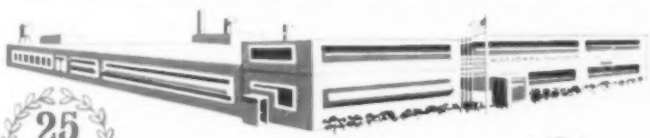

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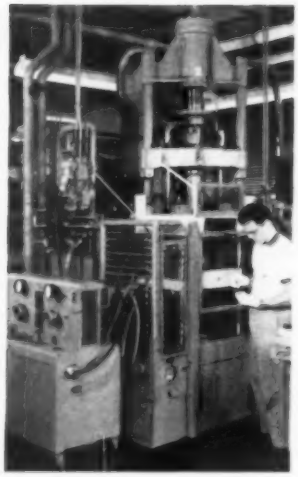

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book reviews

COPE'S PLASTICS BOOK

Dwight Cope. President, Cope Plastics. Edited by Floyd Dickey. Head, Industrial Education Dept., John Adams High School, South Bend, Indiana. 272 pages. The Goodheart-Wilcox Co., Inc., Publishers.

To keep a book technically objective and scientically accurate and at the same time absorbing is a skill possessed by few writers. Among these few are Dwight Cope. Since this volume is for the professional and the layman, too, it is to Mr. Cope's ability that we can thank for many a pleasant evening. Starting with 'facts about plastics' through do-it-yourself projects to the commercial applications for various types of plastics materials, the book maintains the reader's interest.

Can you remember those wonderful pre-television days and evenings too, with those evening and weekend projects of building an end table, or a lamp, or outdoor furniture? Remember those 'conversation' pieces that started off as table lamps and ended up as ash trays? But we never would admit that the reason for the change in product was due to the fact that the do-it-yourself prints weren't clear enough (how could we all our friends and neighbors know us as an engineer). There are about 90 do-it-yourself projects in the book, projects that were submitted by high school and university students. Each project has a material list and of utmost importance to us do-it-yourself fans, a numbered process sheet. Our children, with the help of the writer, did four pieces; all came out as they should and are 'conversation' pieces because they are that good.

This book is a worthwhile investment to the practical engineer and parent. Let us hope that Dwight Cope does not sit back on his laurels, but instead will give us more of the same in the near future.

Irving H. Kellman

HANDBOOK OF MATERIAL TRADE NAMES, SUPPLEMENT 2 TO 1953 EDITION

O. T. Zimmerman and Irvin Lavine. Published by Industrial Research Service, Inc., Dover, N. H., 1957, 356 pages, $13.75.

This second supplement, just published, follows and completes Supplement 1 published in 1956 and reviewed in the SPE Journal issue of August 1957. Like the previous volumes, it has three major sections:

1. The trade name section which lists and describes the materials alphabetically.

2. The classification section wherein the above products are classified according to their uses and properties.

3. The directory section which gives the address of the manufacturers of all listed products and the nomenclature of the products he manufactures.

An appendix gives the changes of names and addresses which occurred since the publication of Supplement is a great helper and time saver which belongs on every chemist's desk.

POLYURETHANES

Bernard A. Dombrow, Reinhold Publishing Corporation, New York (1957).

The author has clearly presented the basic chemistry of Isocyanates and their reactions with hydroxyl containing materials to produce rigid and flexible foams, adhesives, coatings, elastomers, and textile finishes. General formulations and manufacturing techniques have been described in a manner comprehensible to the layman. The physical properties of representative products and sources of raw materials and finished products were given. The book contained numerous photographic reproductions of the products and their processing. Analytical methods and safety precautions were included. This was not a highly technical work but contained a bibliography which was selected to give technical coverage.

W. R. Lawton

EMULSIONS, THEORY AND PRACTICE

Paul Becher, Reinhold Publishing Corp., New York (1957).

The author gives a clear explanation with good illustrating examples of the modern theories of emulsions. The chemistry of emulsifying agents is well written and classified. The bibliography is huge and references are of recent date. Techniques of forming emulsions and the types of equipment used are illustrated. Emulsion formulae and their uses in industry are given. Techniques of demulsification are included. The author describes the test methods for evaluation of emulsions and the theory behind the methods used. A comprehensive list of emulsifiers, their trade names, manufacturers, composition, and type is included. This book is a valuable tool for theoretical and commercial workers in the fields of emulsion and surface chemistry.

W. R. Lawton

TEXTILE CHEMICALS AND AUXILIARIES

Second Edition. Edited by Henry C. Speel and E. W. K. Schwartz. Reinhold Publishing Corporation, N.Y.C. 545 pages. Price: $13.50.

While written primarily to serve as an up-to-date reference for chemists and engineers in the textile processing field, the growing use of resins in textile finishing makes this an interesting text for a certain segment of the plastics industry. Particularly so, since so many of today's synthetic fibers are chemically related to plastics.

The editors are consulting chemists with long experience in the textile field. Most of the chapters (18 out of 24) were either authored or co-authored by specialists in the areas covered. This adds to the value of the book and, as is the case when specialists are given the platform, assures timely authoritativeness.

The chapter on synthetic resins is comprehensively written. Each resin is treated individually, complete with structural formula, properties, forms available and trade names. Synthetic resins are used in the textile industry to impart crease resistance, water resistance and the desired "hand," to control shrinkage, and also as binding mediums to hold various types of finishing and sizing materials. Indeed, the dependence of textiles on synthetic resins has now become of major importance, and many of the functional properties and successful applications of textiles are possible only because of synthetic resins.

The book is well indexed by author and subject. In addition, there is a lengthy and useful bibliography at the close of each chapter.

Unfortunately, the book is marred somewhat by careless proof-reading, for typographical errors abound.

Charles W. Kopf

DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS

Irving N. Sax. Published by Reinhold Publishing Corp., New York, N.Y., 1957, 1476 pages, $22.50.

This book is a revision of "Handbook of Dangerous Materials" previously written by the same author. That this book needed a great deal of corrections and additions was obvious to all its readers. It appears that there have been quite a few improvements, additions in the nomenclature, corrections in the listings and welcome changes. On the other hand, to say that the second book does not leave a great deal to be desired would be showing signs of morbid and dangerous optimism. There are still omissions galore—and important ones at that—and many data which one expects to find in such a book are lacking. As a general example, there are countless instances where the toxicity is marked "unknown" although it is given in other toxicological books. This is a very expensive book. Let's wish the author better luck in his third effort. We shall wait for it.

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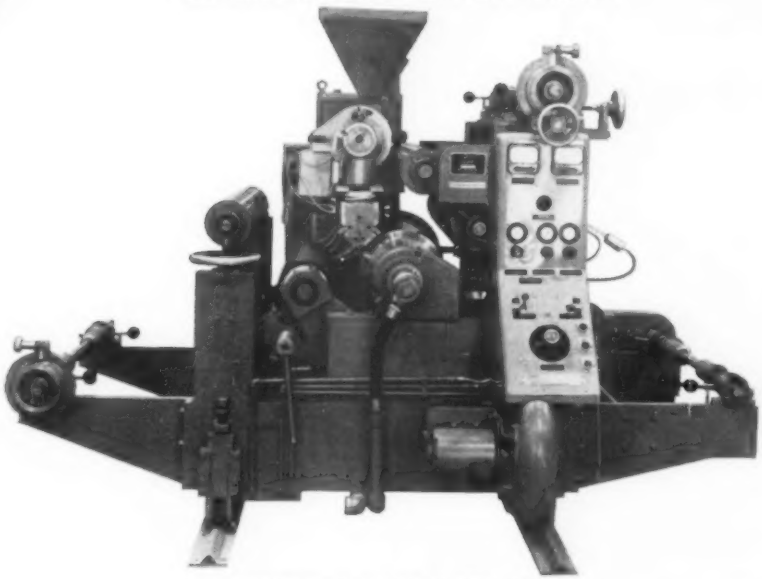

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